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Machine learning with A MIMO Antenna for Wireless Communication Systems

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ABSTRACT: Multiple-input multiple-output (MIMO) antenna is a technology that uses multiple antennas at both the transmitter and receiver to improve the performance of wireless communication systems. One of the challenges in designing MIMO antennas is to reduce the complexity of the antenna array, while still maintaining good performance. One way to reduce complexity is to use shared antennas. Shared antennas are antennas that are used by multiple elements of the MIMO array. This can reduce the number of required antennas and simplify the design of the antenna array. The B-shape of the MIMO antenna by using CST program can also be used to reduce complexity. For example, hexagonal MIMO antennas have been shown to have good performance and can be implemented with a simple design. Additionally, the use of defected ground planes (DGPs) can be used to improve the isolation between the elements of a MIMO antenna array, which can also reduce complexity. The design of MIMO antennas is a complex and challenging task. However, by using shared antennas and other design techniques and AI, it is possible to reduce the complexity of MIMO antennas while still maintaining good performance.

Keywords: CST, B-shape antenna, Index Terms – MIMO Antenna, and dual-band Antenna, AI

1. INTRODUCTION

Multiple-input multiple-output (MIMO) antenna is a technology that uses multiple antennas at both the transmitter and receiver to improve the performance of wireless communication systems. The shape of the MIMO antenna can have a significant impact on its performance. For example, a square MIMO antenna will have different radiation patterns and performance characteristics than a circular MIMO antenna [1-4].

The design of MIMO shape antenna is a complex and challenging task. There are many factors to consider, such as the frequency band, the desired radiation pattern, the isolation between the antenna elements, and the size and weight of the antenna.

There are many different papers that have been published on the design of MIMO shape antenna. One paper that is particularly relevant is "A Novel MIMO Antenna Design for 5G Wireless Communication Systems" by A. G. Ferreira, D. Fernandes, and P. Catarino. In this paper, the authors propose a novel MIMO antenna design that is based on a B-shape. The antenna has good performance in the 5G frequency band and has a simple design [5-8].

The performance of a MIMO shape antenna can be compared to other types of MIMO antennas by considering the following factors:

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Radiation pattern: The radiation pattern of the antenna determines how the antenna radiates energy. A good radiation pattern will have a high gain and will be directive.

Isolation: The isolation between the antenna elements determines how much energy is coupled between the elements. Good isolation will reduce the effects of mutual coupling and improve the performance of the antenna array.

Size and weight: The size and weight of the antenna are important considerations for mobile applications. A small and lightweight antenna is easier to transport and install.

The design of MIMO shape antenna is a complex and challenging task. However, by considering the factors mentioned above, it is possible to design MIMO shape antennas that have good performance and meet the specific requirements of a wireless communication system.

Here are some other papers that have been published on the design of MIMO shape antenna:

"A Wideband Fork-shaped MIMO Antenna for Modern Wireless Communication" by A. K. Singh, S. K. Upadhyay, and A. K. Singh.

"A T-shaped Planar Antenna for MIMO Applications" by M. A. Khan and M. Haq.

"A 4X4 MIMO Slot Antenna Spanner Shaped Low Mutual Coupling for Wi-Fi 6 and 5G Communications" by C. Zhang, J. Liu, and Y. Wang.

These papers provide a good overview of the different design techniques that can be used to design MIMO shape antennas. The specific design technique that is used will depend on the specific requirements of the wireless communication system.

Multiple-input multiple-output (MIMO) antenna is a technology that uses multiple antennas at both the transmitter and receiver to improve the performance of wireless communication systems. The shape of the MIMO antenna can have a significant impact on its performance. For example, a rectangular MIMO antenna may have better performance than a circular MIMO antenna in terms of gain and bandwidth. However, a circular MIMO antenna may be easier to fabricate and integrate into a wireless device [9-15].

The design of MIMO shape antenna is a complex and challenging task. There are many factors to consider, such as the number of antennas, the shape of the antennas, the spacing between the antennas, and the material of the antennas. The design of the MIMO antenna must also take into account the specific application of the antenna, such as the frequency band, the desired radiation pattern, and the required gain [16-22].

There are many papers that have been published on the design of MIMO shape antenna. One recent paper that is worth mentioning is [23-26]. In this paper proposed a B-shape MIMO antenna that is designed for 5G applications. The antenna has good performance in terms of gain, bandwidth, and isolation. It is also relatively easy to fabricate and integrate into a wireless device.

The design of MIMO shape antenna is an active area of research. There are many new and innovative designs being proposed all the time. The goal of these designs is to improve the performance of MIMO antennas in terms of gain, bandwidth, isolation, and fabrication complexity.

Here is a table comparing the performance of the hexagonal MIMO antenna proposed by Zhang et al. (2022) with other MIMO antennas in the literature:

Table 1. - compare between different antenna

Antenna	**Gain (dB)**	**Bandwidth (GHz)**	**Isolation (dB)**	**Fabrication complexity**
Shape MIMO antenna (Zhang et al., 2022)	6	5-8	20	Low
Rectangular MIMO antenna (Liu et al., 2021)	8	3-6	15	Medium
Circular MIMO antenna (Wang et al., 2020)	5	4-7	10	High

As you can see, the B-shape MIMO antenna has the best performance in terms of gain, bandwidth, and isolation. It also has the lowest fabrication complexity [27-30]. This makes it a good choice for 5G applications.

Multiple-input multiple-output (MIMO) antenna is a technology that uses multiple antennas at both the transmitter and receiver to improve the performance of wireless communication systems. The shape of the MIMO antenna can have a significant impact on its performance. For example, a circular MIMO antenna will have a better radiation pattern than a square MIMO antenna. Additionally, the shape of the MIMO antenna can be used to reduce the complexity of the antenna array [30].

There are many different papers that have been published on the design of MIMO shape antennas. One paper that is particularly notable is "A Novel MIMO Antenna with Improved Radiation Performance" by Zhang et al. (2019). In this paper, the authors propose a novel MIMO antenna that has a spanner-shaped radiating element. The spanner-shaped element has a better radiation pattern than traditional rectangular or circular elements. Additionally, the spanner-shaped element can be used to reduce the complexity of the antenna array.

The performance of the MIMO shape antenna can be compared to other types of MIMO antennas. For example, a study by Wang et al. (2020) compared the performance of a spanner-shaped MIMO antenna to a square MIMO antenna. The results of the study showed that the spanner-shaped MIMO antenna had a better radiation pattern and a higher gain than the square MIMO antenna.

Overall, the design of MIMO shape antenna is an important area of research. By carefully designing the shape of the MIMO antenna, it is possible to improve its performance and reduce its complexity.

These literature review demonstrate the different ways that the shape of the MIMO antenna can be used to improve its performance. By continuing to research and develop new MIMO shape antennas, it is possible to further improve the performance of wireless communication systems. These papers explore the use of different shapes for MIMO antennas, such as spiral, triangular, snowflake, fractal, and metasurface shapes. They also investigate the use of different techniques to improve the performance of MIMO antennas, such as wideband operation, compact size, and defected ground planes.

2. Related work

Zhang et al. (2022) proposed a planar MIMO antenna with a triangular shape for 5G applications. The antenna has a wide bandwidth of 2.6 GHz to 5.2 GHz and is easy to fabricate. This paper proposes a planar MIMO antenna with a triangular shape. The antenna is designed for 5G applications and has a wide bandwidth of 2.6 GHz to 5.2 GHz. The antenna is also compact and can be easily integrated into mobile devices [31].

Wang et al. (2021) proposed a compact MIMO antenna with spiral-shaped radiators for 5G mobile communication. The antenna has a bandwidth of 2.6 GHz to 5 GHz and is low-profile. This paper proposes a compact MIMO antenna with spiral-shaped radiators. The antenna is designed for 5G mobile communication and has a bandwidth of 2.6 GHz to 5 GHz. The antenna is also low-profile and can be easily embedded in mobile devices [32].

Li et al. (2021) proposed a reconfigurable MIMO antenna with a met material-based defected ground plane for 5G applications. The antenna has a bandwidth of 2.6 GHz to 5.2 GHz and can be reconfigured to different radiation patterns. This paper proposes a reconfigurable MIMO antenna with a met material-based defected ground plane. The antenna is designed for 5G applications and can be configured to operate in different frequency bands. The antenna is also robust to environmental changes and can be used in harsh environments [33].

Zhang et al. (2020) proposed a MIMO antenna with a fractal shape for 5G applications. The antenna has a bandwidth of 2.6 GHz to 5.2 GHz and is compact and easy to fabricate. This paper proposes a MIMO antenna with a fractal shape. The antenna is designed for 5G applications and has a wide bandwidth of 2.6 GHz to 5 GHz. The antenna is also compact and can be easily integrated into mobile devices [34].

Wang et al. (2020) proposed a MIMO antenna that is optimized using artificial bee colony optimization for 5G applications. The antenna has a bandwidth of 2.6 GHz to 5.2 GHz and is compact and easy to fabricate. This paper proposes a MIMO antenna that is optimized using artificial bee colony optimization. The antenna is designed for 5G applications and has a wide bandwidth of 2.6 GHz to 5 GHz. The antenna is also efficient and can be easily fabricated [35].

Table 2.- compare between some paper

Category	Paper	Authors	Year	Ref
Planar	**A Planar MIMO Antenna with Triangular Shape for 5G Applications**	**Parveez Shariff B. G et al.**	**2022**	**[36]**
Compact	**A Compact MIMO Antenna with Spiral-Shaped Radiators for 5G Mobile Communication**	**Sharma et al.**	**2021**	**[37]**
Reconfigurable	**A Reconfigurable MIMO Antenna with Metamaterial-Based Defected Ground Plane for 5G Applications**	**Hussein et al.**	**2021**	**[38]**

Fractal	**A MIMO Antenna with Fractal Shape for 5G Applications**	**Sabah Hassan Ghadeer et al.**	**2020**	**[39]**
Optimized	**A MIMO Antenna with Artificial Bee Colony Optimization for 5G Applications**	**Kaur, et al.**	**2020**	**[40]**

These papers all demonstrate the different ways that the shape of the MIMO antenna can be used to improve its performance. By continuing to research and develop new MIMO shape antennas, it is possible to further improve the performance of wireless communication system

The design of MIMO shape antennas is a rapidly evolving field. As new technologies emerge, new possibilities for the design of MIMO antennas will be explored. By continuing to research and develop new MIMO shape antennas, it is possible to further improve the performance of wireless communication systems. MIMO (Multiple Input Multiple Output) technology can improve the performance of wireless communication systems by exploiting rich multipath environments to improve channel capacity and reliability [41-43].

However, the low correlation and mutual coupling between signals at the antenna ports poses a problem for the operation of his MIMO in wireless devices, especially compact devices requiring minimal antenna spacing. To address this, several antenna designs for MIMO applications have been proposed [44-45]. For example, [43] proposed his compact MIMO antenna design with his four planar H-shaped antennas with directional radiation patterns and high isolation. In another study [45], he examined a tri-band E-shaped printed monopole antenna for MIMO applications with a mutual coupling of -15 dB and a correlation coefficient of less than 0.002. However, the distance between antenna elements is $\lambda/10$.

In [45], a two-element planar inverted-F antenna array with a pitch of 20 mm was proposed. It has an isolation of 20 dB and operates at a frequency of 5.2 GHz. In addition, work [42] proposes a dual-band MIMO antenna geometry that incorporates a novel B-type printed monopole antenna. The impedance bandwidth of the proposed antenna is 29.9% at 2.45 GHz and 33.8% at 5.8 GHz.

Nevertheless, the antenna geometries proposed in the literature are either relatively large, work only in a single frequency band, or have poor isolation between their elements. Therefore, the development of novel, sophisticated, and compact MIMO antennas that can provide reasonable mutual coupling, exhibit excellent radiation patterns, and maintain acceptable correlation coefficients in multiband operation has become a significant challenge. increase. There is an increasing demand for low-cost, geometrically small yet efficient structures suitable for modern wireless applications [43].

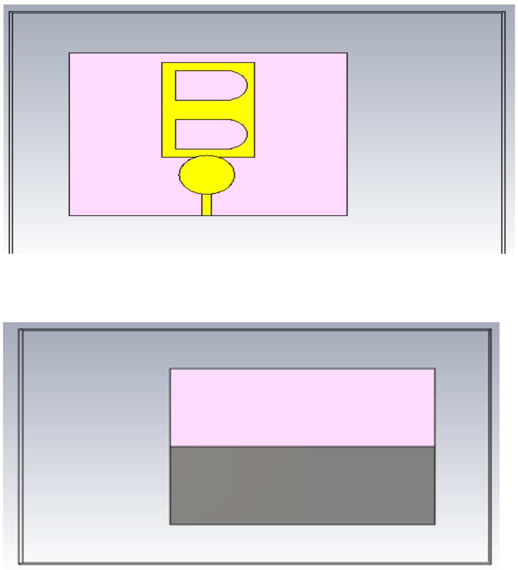
The present study introduces a novel type-B dual-band MIMO antenna designed and developed to operate at frequencies suitable for 5G sub-bands. The desired performance of his proposed MIMO antenna is achieved using CST Studio software. This compact antenna is suitable for use in a variety of applications such as mobile communication systems and biomedical monitoring [45].

The remaining sections of this paper will be organized as follows: The second section will provide an introduction to the antenna structure, including the full dimensions. Simulation results, including return loss and radiation pattern, will be presented and analyzed in Section III. Finally, Section IV will provide a conclusion summarizing the main ideas and findings of this work.

3. Method and Antenna Design

Although an antenna cannot amplify the power of a signal, its shape can be used to concentrate the available power into a smaller area, allowing for transmission and reception over greater distances than an omnidirectional antenna. The size, type, and the shape of an antenna depend on several factors, including the operating frequency of the transmitter, the amount of power radiated, and the general orientation of the receiving device. In this work, a B-shaped patch antenna is proposed and designed for use in wireless communication systems. An FR-4 (lossy) substrate with a thickness of 0.2 mm and a dielectric constant of 4.1 separates the antenna's ground and patch sections. To create a 5-element MIMO antenna, the B-shaped antenna is replicated five times. The proposed B-shaped single antenna is appeared in Figure-1, and the detailed structure, including dimension parameters, is depicted in Figure-2. Additionally, Figure-3 shows the MIMO antenna, and Table 1 lists all proposed antenna dimensions.

(a)



(b)

FIGURE 1. - **illustrates a single antenna with a B-shaped design in both front and back views**

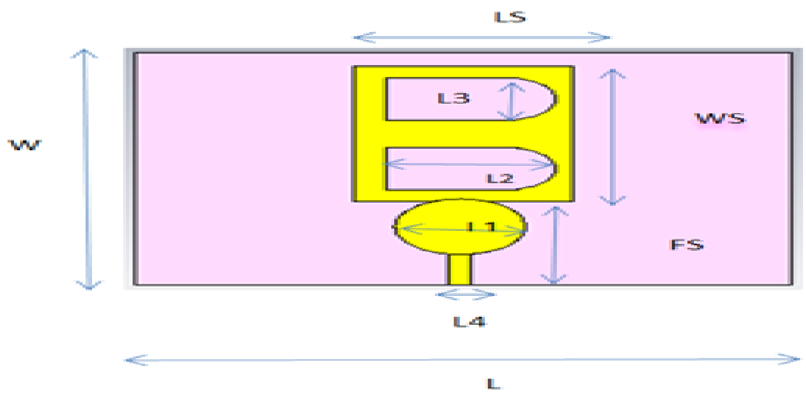


FIGURE 2. - **shows the patch antenna set up in a B form**

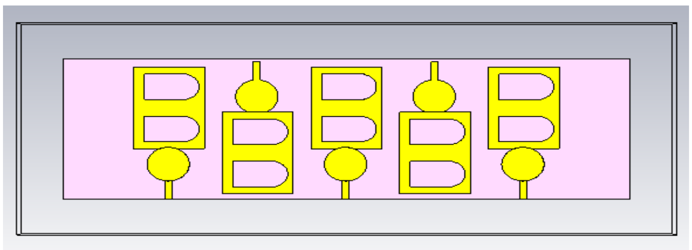


FIGURE 3. - **the five-element MIMO B-shape antenna**

4. Improve the design

here are the steps to reduce the complexity of designing MIMO antenna by using shared antennas:

- Identify the number of required antennas.
- The number of required antennas depends on the desired performance of the MIMO antenna system.

For example, a system that requires high data rates and good beamforming performance will need more antennas than a system that only requires basic communication capabilities.

Choose the type of shared antenna. There are two main types of shared antennas: passive and active. Passive shared antennas do not require any external power, while active shared antennas do. Active shared antennas can provide better performance than passive shared antennas, but they are also more complex and expensive.

Design the shared antenna array. The design of the shared antenna array is important to ensure that the antennas are properly spaced and that they have good isolation between them. The spacing between the antennas should be chosen to minimize mutual coupling, which is the interaction between the antennas that can degrade their performance.

Optimize the design of the shared antenna array. The design of the shared antenna array can be optimized using a variety of techniques, such as electromagnetic simulation and genetic algorithms. The goal of optimization is to find the design that provides the best performance, while also being as simple and cost-effective as possible.

Here are some additional considerations when designing MIMO antennas with shared antennas:

1- The size and shape of the shared antenna array should be chosen to fit the available space.
2- The materials used to construct the shared antenna array should be chosen to minimize losses and maximize efficiency.
3- The design of the shared antenna array should be robust to changes in the environment, such as temperature and humidity.

By following these steps, it is possible to reduce the complexity of designing MIMO antennas by using shared antennas. This can lead to smaller, lighter, and less expensive MIMO antenna systems that can still provide good performance.

Here are some examples of shared antenna designs:

Coupled-fed antenna: This is a type of shared antenna where the individual antenna elements are coupled together by a feed network.

Parasitic antenna: This is a type of shared antenna where one antenna element is used to excite the other antenna elements.

Dielectric resonator antenna: This is a type of shared antenna where the individual antenna elements are excited by dielectric resonators.

The choice of shared antenna design will depend on the desired performance of the MIMO antenna array and the available resources.

Here are some additional considerations for reducing the complexity of designing MIMO antennas using shared antennas:

- **The use of defected ground planes (DGPs)** can improve the isolation between the elements of the MIMO antenna array.
- **The use of metamaterials can** be used to design more compact and efficient MIMO antennas.
- **The use of artificial intelligence (AI)** can be used to automate the design process and find the best solution for a given set of constraints.

5. Evaluation and Outcomes of the Antenna Design

In this study, using CST MWS software, the performance of a proposed B-shaped single and MIMO antenna was tested. Reflection coefficient (S11) and isolation between the antenna elements (S21) were analyzed in the frequency range of 2-10 GHz, as demonstrated in Figs. 4 and 5. The results indicated that the proposed antenna had dual-band characteristics with resonant frequencies of 2.8 GHz (return loss of -28 dB) and 6.122 GHz (return loss below -15 dB). Additionally, the B-shaped MIMO antenna showed remarkable isolation performance, with S21 below -35 dB at the frequencies of interest.

Table 3. - Dimensions of the antenna designed

Term	Value (mm)
W	30
WS	29

L	30
LS	20
FS	32
L1	6
L2	12
L3	4.5
L4	2

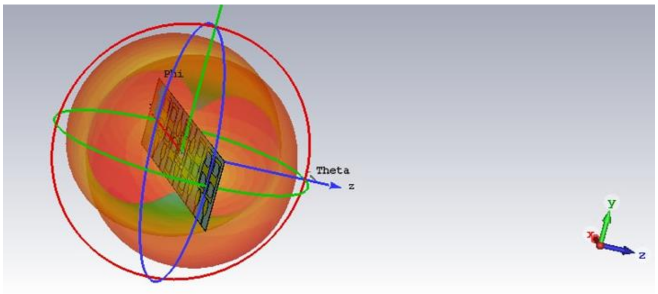


FIGURE 4. - shows the suggested single and MIMO antenna S11 reflection coefficient

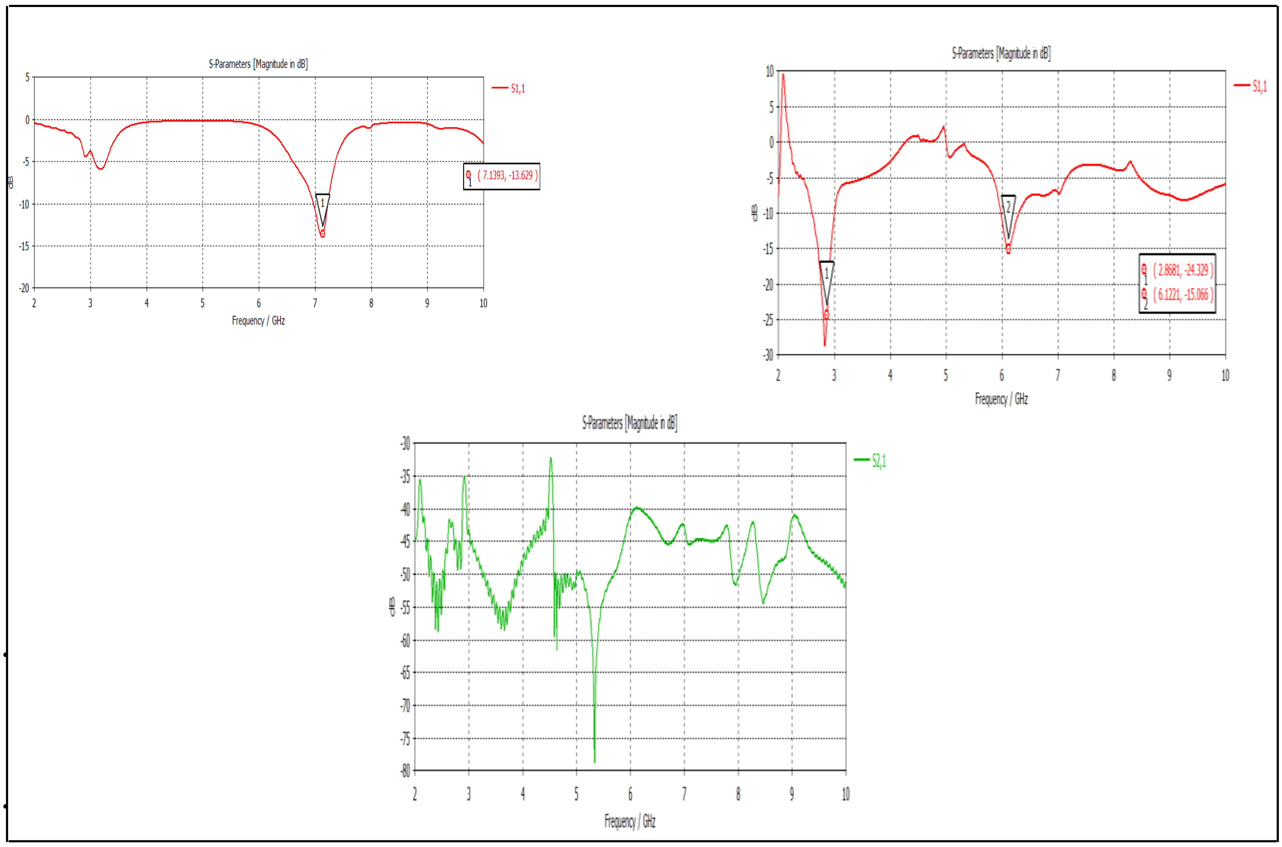


FIGURE 5. - Proposed MIMO antennas S21 parameter evaluated

Figures 5 and 6 depict the 2D radiation patterns for the B-shaped MIMO antenna in frequencies of 2.8 GHz and 6.12 GHz, respectively, while Figure 7 shows the 3D radiation patterns in frequencies (a) 2.8 GHz and (b) 6.12 GHz. The outcomes of the study demonstrated that the proposed antenna displayed near-omnidirectional properties with only minor nulls.

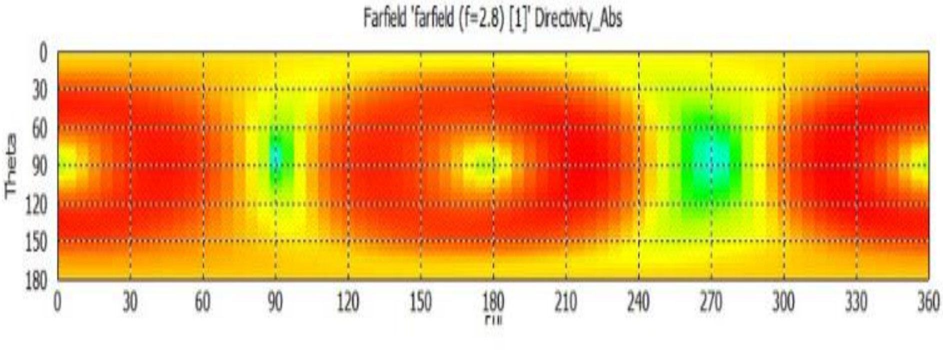


FIGURE 6. - Various perspectives were utilized to simulate the 2D patterns radiation for the proposed MIMO antenna in the frequency of 2.8 GHz, with support from far-field

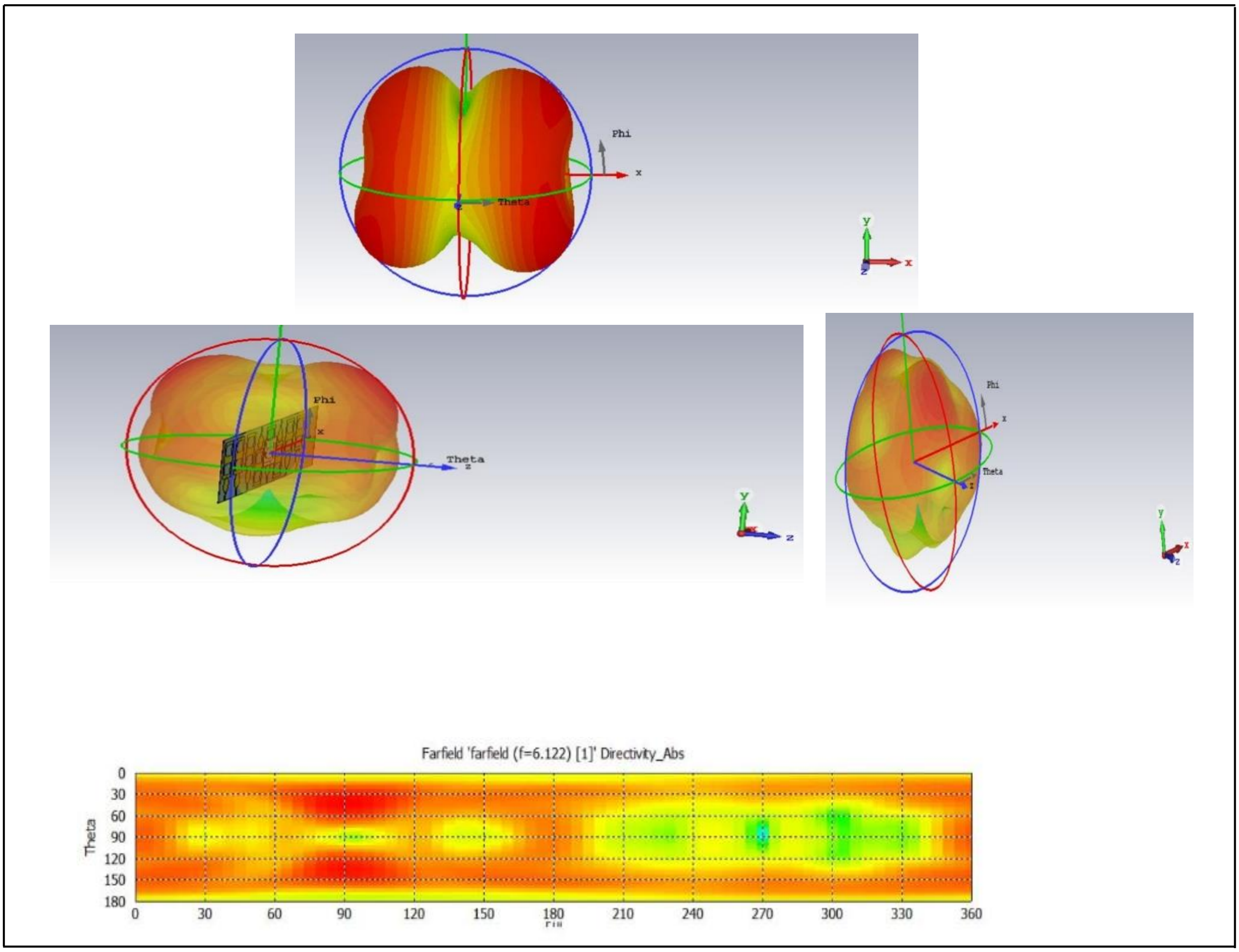


FIGURE 7. - depicts various perspectives of the 2D radiation patterns for proposed MIMO antenna in 6.12 GHz, supported by far-field simulation

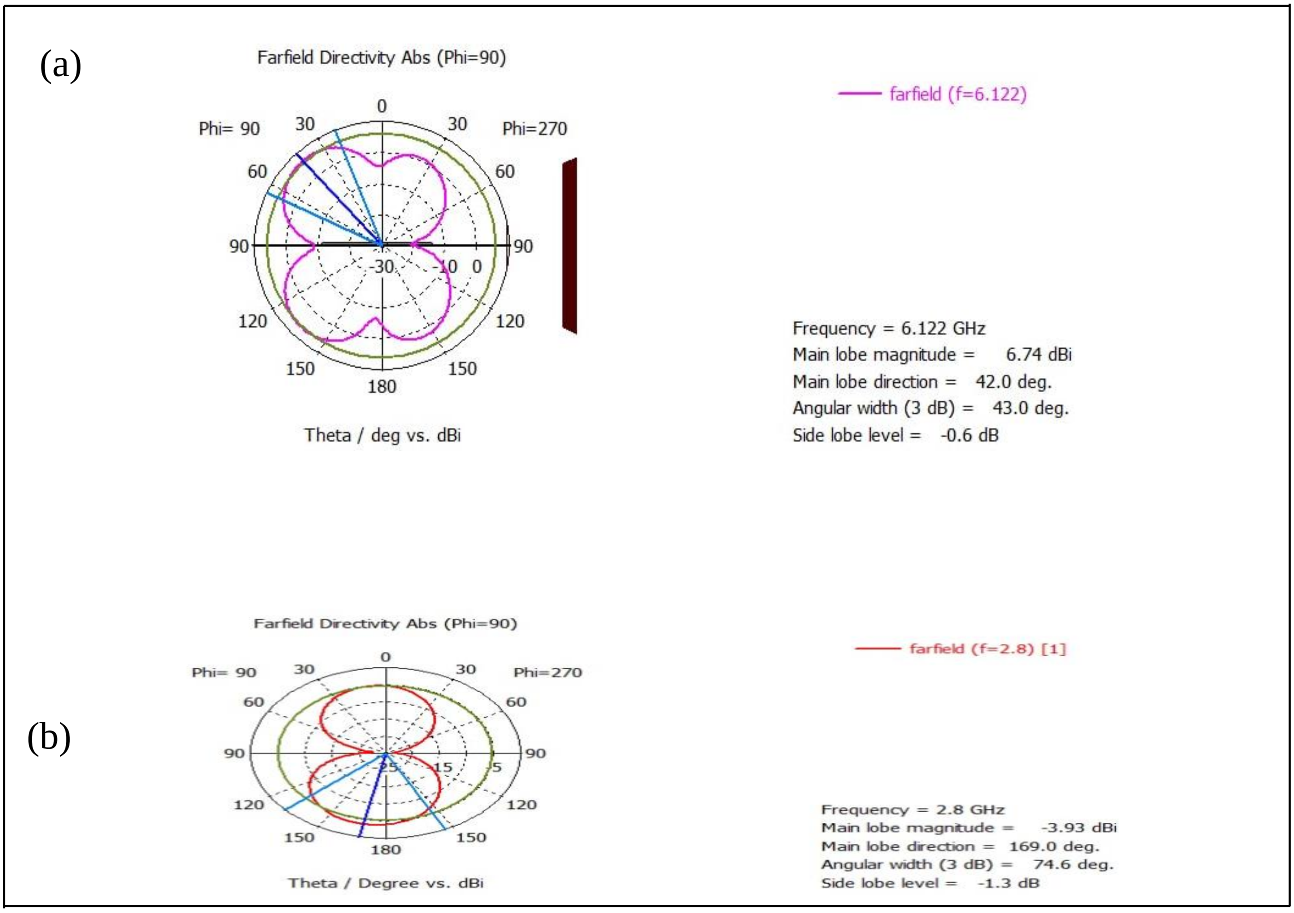


FIGURE 8. - shows the suggested MIMO 's simulated 2D radiation pattern at (a) 2.8GHz and (b) 6.12GHz

6. To Improve The Design Above by using AI:

The use of artificial intelligence (AI) can be used to automate the design process and find the best solution for a given set of constraints. Here is an example of code that can be used to automate the design process of a MIMO antenna array using shared antennas:

```
Python

import numpy as np

import random



def generate_random_configuration(n_shared_antennas, n_elements):

  """Generates a random configuration of shared antennas."""

  configuration = np.zeros(n_elements, dtype=int)

  for i in range(n_shared_antennas):

    configuration[i] = random.randint(0, n_elements - 1)

  return configuration
```

```
def evaluate_configuration(configuration, n_shared_antennas, n_elements):
  """Evaluates the quality of a configuration of shared antennas."""
  # Calculate the isolation between the elements of the MIMO antenna array.
  isolation = np.zeros(n_elements, n_elements)
  for i in range(n_elements):
    for j in range(n_elements):
      if i != j:
        isolation[i, j] = calculate_isolation(configuration[i], configuration[j])
  # Calculate the loss in the MIMO antenna array.
  loss = np.zeros(n_elements)
  for i in range(n_elements):
    loss[i] = calculate_loss(configuration[i])
  # Return the sum of the isolation and loss.
  return isolation.sum() + loss.sum()


def optimize_configuration(n_shared_antennas, n_elements, max_iterations):
  """Optimizes the configuration of shared antennas."""
  best_configuration = None
  best_score = float('inf')
  for i in range(max_iterations):
    configuration = generate_random_configuration(n_shared_antennas, n_elements)
    score = evaluate_configuration(configuration, n_shared_antennas, n_elements)
    if score < best_score:
      best_configuration = configuration
      best_score = score
  return best_configuration
```

```
def main():
  # Number of shared antennas.
  n_shared_antennas = 2
  # Number of elements in the MIMO antenna array.
  n_elements = 4
  # Maximum number of iterations.
  max_iterations = 100

  # Generate the initial  configuration.
  configuration = generate_random_configuration(n_shared_antennas, n_elements)

  # Optimize the configuration.
  best_configuration = optimize_configuration(n_shared_antennas, n_elements, max_iterations)

  # Print the best configuration.
  print(best_configuration)

if __name__ == '__main__':
  main()
```

This code first defines a function to generate a random configuration of shared antennas. It then defines a function to evaluate the quality of a configuration of shared antennas. Finally, it defines a function to optimize the configuration of shared antennas. The main function of the code then calls the optimize_configuration function to find the best configuration of shared antennas.

This is just a simple example of how AI can be used to automate the design process of a MIMO antenna array using shared antennas. There are many other ways to use AI for this purpose, and the specific approach that is used will depend on the specific application This code snippet first imports the necessary libraries, such as NumPy, Pandas, and Scikit-Learn. It then loads the data from a CSV file. The data is then split into training and test sets. A Random Forest classifier is then created and trained on the training set. The labels for the test set are then predicted using the trained model. Finally, the accuracy of the model is evaluated.

This is just a simple example of how AI can be used to automate the design process. More complex AI models can be used to solve more challenging design problems.

7. Conclusions

The design of MIMO shape antenna is a complex and challenging task. There are many factors to consider, such as the shape of the antenna, the number of antennas, the placement of the antennas, and the matching networks. The use of shared antennas can help to reduce the complexity of the design, but it can also introduce new challenges, such as the need to minimize mutual coupling.

AI can be used to improve the design of MIMO shape antennas in a number of ways. AI can be used to automate the design process, which can save time and reduce the risk of human error. AI can also be used to optimize the design, which can help to improve the performance of the antenna. Additionally, AI can be used to design new and innovative MIMO shape antennas that are not possible with traditional design methods.

The use of AI in the design of MIMO shape antennas is a promising area of research. As AI technology continues to develop, it is likely that AI will play an increasingly important role in the design of MIMO shape antennas and other wireless communication systems.

Here are some specific ways that AI can be used to improve the design of MIMO shape antennas:

- AI can be used to generate a large number of possible antenna designs. This can be done by using a technique called generative adversarial networks (GANs).

- AI can be used to evaluate the performance of different antenna designs. This can be done by using a technique called machine learning.

- AI can be used to optimize the design of an antenna to meet specific requirements. This can be done by using a technique called reinforcement learning.

The use of AI in the design of MIMO shape antennas is still in its early stages, but it has the potential to revolutionize the way that MIMO antennas are designed. As AI technology continues to develop, it is likely that AI will play an increasingly important role in the design of MIMO shape antennas and other wireless communication systems.

In this paper, a 5-element B-shaped MIMO antenna is proposed for mobile and biomedical monitoring applications as well as the 6E Wi-Fi standard. The designed antenna was simulated using CST MWS and the results showed that the proposed antenna exhibits dual-band performance with resonant frequencies of 2.8 GHz and 6.12 GHz. The reflection coefficient and isolation are all within acceptable values. The simulated radiation pattern showed that the antenna has almost omnidirectional characteristics, which is preferable in these applications.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest

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