Designing of Ultra - Wideband Antenna for Wearable Application

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Abstract: ***This paper describes the design of an ultra - wideband (UWB) antenna which works above the frequency of 1GHz and resonates at 4GHz for wearable applications. Initially, to achieve the wideband antenna design, the parameters related to the microstrip patch antenna have been used. Further, to achieve the wideband range of frequency the ground plane of this antenna is designed as a semi - rectangular plane. To improve the antenna parameters mainly return loss, gain, directivity, the metamaterial structures are designed on the above of the microstrip patch antenna which is usually placed at a distance of 22.5mm. Then for wearable application, the antenna has to be very flexible and lightweight, therefore, the substrate for designing antenna and metamaterial structure, the polyester material has been used whose dielectric constant is 3.2 and height is 1.6mm. Then the research concentrates on the comparison study between three different shapes of MTM unit cell array. MTM structures are based on Artificial Magnetic structures which are commonly known as Split Ring Resonators (SRR). The proposed antenna design with metamaterial is analyzed and simulated by Ansoft HFSS software.***

Keywords: Microstrip Patch Antenna; HFSS; Metamaterial; Split ring resonators (SRR); ultra - wideband antenna (UWB); Wearable application

1. Introduction

Nowadays, the ultra - wideband antenna is becoming popular in today's market because of its design structure, wide bandwidth, high data rates, low power consumption and cheapest. The most attractive property of this antenna is it has wide bandwidth which is greater than 502MHz, so one UWB antenna can be used to replace multi - narrower antenna's which may overcome the usage of number of antennas. The microstrip patch antenna chosen here to design UWB antenna because of its low - cost, light weight, easy to fabricate and having ease of fabrication.

Designing of UWB antenna has been based only on the natural material like copper, FR - 4 substrate etc. which gives poor performance in the wearable technology as antenna needs to be flexible. When we change the substrate from metallic substrate to fabric material these antenna performances will going to change. So, to achieve good performance of these antenna anew material which are known as MTM has been used. These materials have different properties towards the electromagnetic radiations such as negative refractive index, negative permittivity and permeability etc. due to its capacitive effect. These properties of metamaterial are cannot be found in natural materials and thus it can provide better solution for antenna performance.

Metamaterial structures are built by forming the array of unit cells in which all the cells are placed at equidistance from each other. The unit cell of MTM can be made of electrical, nonelectrical or of dielectric materials. These MTM structures when added to the microstrip patch antenna they increase the antenna gain, directivity, radiation efficiency and small return loss. Electromagnetic MTM are created by arrangement of multiple elements in repeated manner or in periodically form.

Here the design of MTM is based on the Split Ring Resonators (SRR). It is a pair of parallelly placed loops etched in a dielectric substrate with splits in them at opposite ends.

Wearable antennas have become more popular in the recent technology. They are easily installable, cheapest, maintenance free, weightless. Wearable technologies are useful in the mobile health in terms of improving healthcare and providing data of human body on improved health management and tracking. Wearable ultra - wideband antenna has applications in various field such as medical field for health monitoring where antennas are mounted on the human body or to give the feedback of patients, in sports for athletes, in military applications, etc.

2. Ultra – Wide band Antenna Structure

The design of meta - material based microstrip patch antenna has been designed using widely used High Frequency Simulator Software (HFSS). The ultra - wideband antenna can work above 1GHz of frequency. This antenna is designed by using microstrip antenna's parameters as shown in below fig.

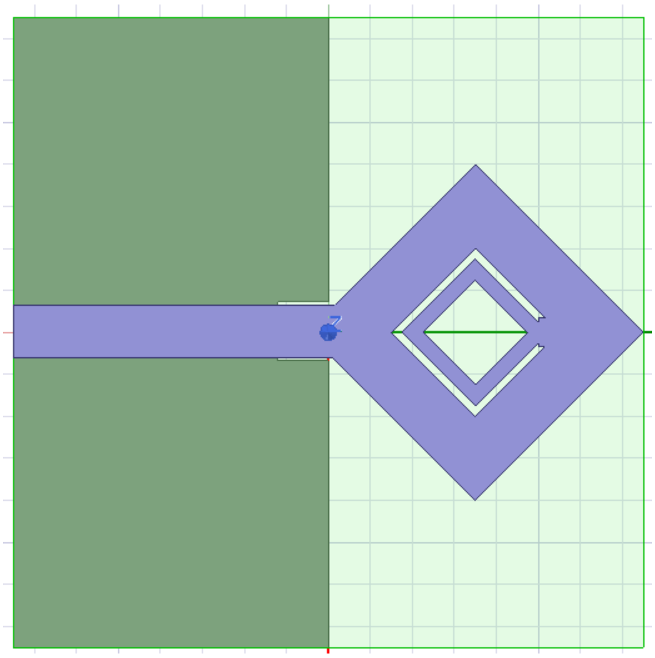

Figure 1: The top view of rhombic ultra - wideband microstrip patch antenna

The substrate used for designing this antenna is of polyester material which has dielectric constant of 3.2 and thickness of 1.6mm. The length and width of substrate is 30.1mm. The patch of antenna is made of a rhombus like structure by keeping all the sides same of length 11.3mm. In middle to that patch outer design, a small hole is made of length 3.53mm. At distance 1mm from that hole one slot like C - shape is designed of length 5.65mm and width of 0.25mm. To achieve 50 ohms impedance, the width of feedline is kept 2.51 mm.

On the other side of substrate, the conducting ground plane is designed of semi – rectangular plane whose length is kept 30.1mm and width is 15mm as to achieve ultra - wideband width. Again, at the top of ground plane a small rectangular notch with dimension of 2.8mm x 2.4mm is proposed to have better impedance of the microstrip antenna.

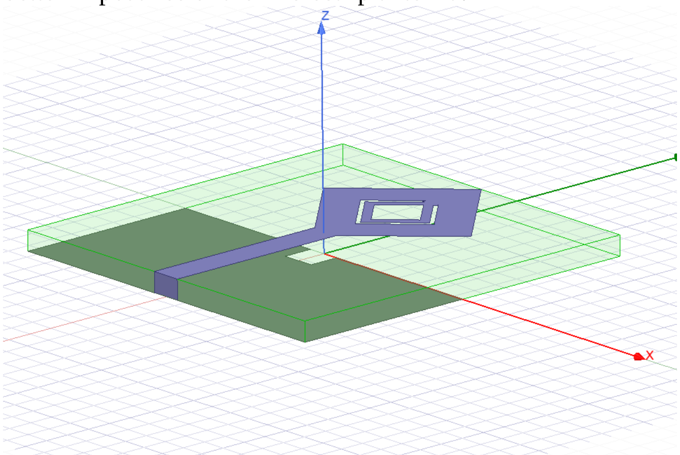

Figure 2: Isometric view of UWB antenna.

The simulated result of UWB antenna without use of MTM structure has been analyzed. The gain of this antenna is 4.2 and VSWR at resonating frequency is 1.27 which is shown in fig.4 and S parameters are shown in below fig 3.

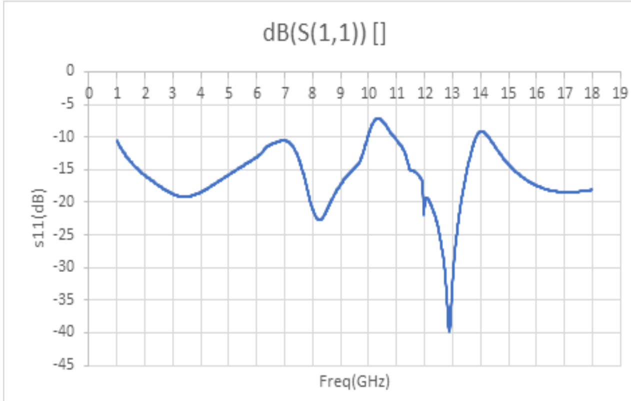

Figure 3: The highest peak of reflection coefficient of UWB antenna is - 39.7dB

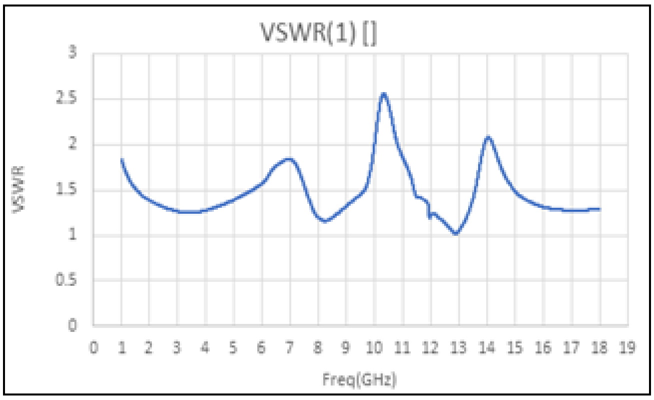

Figure 4: The value for VSWR at 4 GHz is 1.27.

3. Unit Cell of Metamaterial

Here the design of metamaterial is based on the Split Ring Resonator (SRR). It consists of two microstrip circles shaped design with the slits in between them and both the shapes are made like a C - shape by forming the gaps at opposite sides of each ring. The substrate for unit cell of MTM is polyester which has width and length of 10mm. The design of MTM unit cell is shown in below fig5.

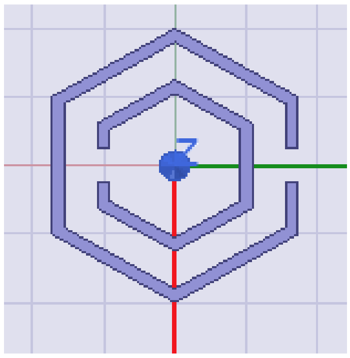

Figure 5: The hexagonal shaped unit cell of MTM.

The hexagonal MTM shape is drawn by keeping all the sides same. The length of each side of outer loop is 4mm and width of that outer loop is 0.4mm. The gap between two loops is 1.1mm and the length of each side of inner loop of hexagon is 2.5mm and keeping the width same as outer loop. Then, the gap slit at each opposite end is of 1mm.

MTM Structure

The MTM structure is formed by forming the array of MTM unit cell. After obtaining the MTM unit cell with different dimensions it is then being duplicated to form 3x3 array which is shown in below fig6.

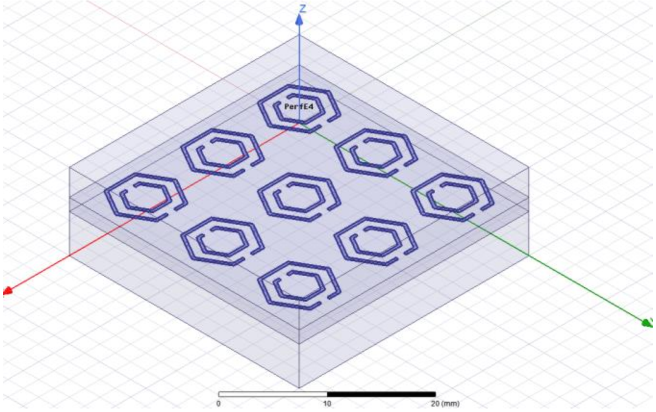

Figure 6: A 3x3 array of hexagonal - MTM Structure.

The overall size for this MTM is 30.1x30.1mm which is kept same as the size of UWB antenna. The boundary conditions and wave ports were used to simulate the unit cell which is shown in below fig7 and fig8.

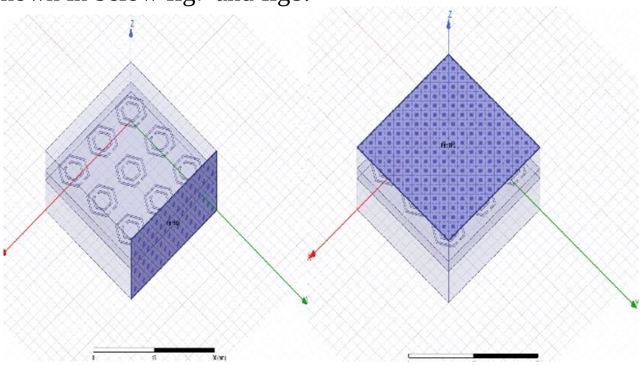

Figure 7: The MTM structure with PEC and PMC boundary conditions

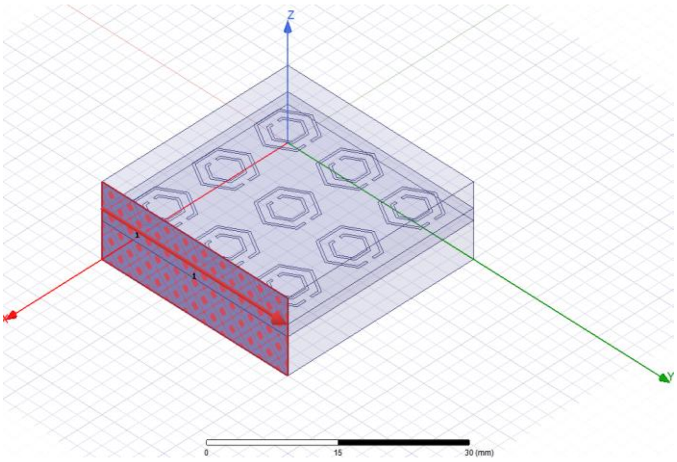

Figure 8: The wave port assigned on the z - faces of MTM

Along the Z - faces the Electric Field boundary conditions were placed. The perfect magnetic boundary condition was placed on the X - a face of unit cell and wave ports 1 and 2 is assigned on the Y - faces of the unit cell. The simulated S parameters are shown in below fig9.

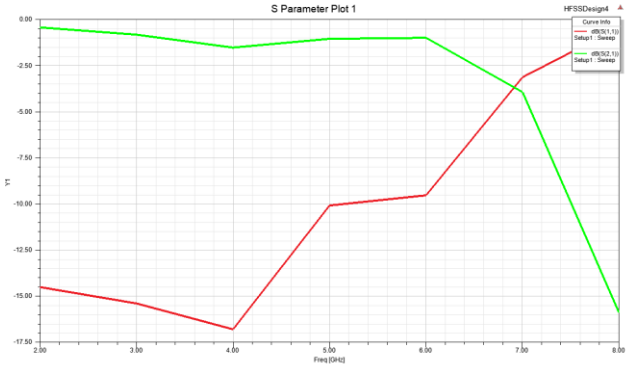

Figure 9: S_{11} and S_{21} parameters of MTM structures.

Here, S11 represents how much power has been reflected from the input port which is also known as reflection coefficient. Here, S11 parameter graph is little below to 0dB, that means there is 10 percent reflection took place. Then S21 parameter of MTM shows that how much transmission from input to output has taken place. So, when there is 10 percent of reflection take place, at a same time 90 percent signal radiates from the antenna.

4. Rhombic Ultra - Wideband Microstrip Patch Antenna with Metamaterial Structure

By doing the literature Survey, it has been concluded that the UWB antenna has the attractive feature such as small size and wide bandwidth. However, the disadvantage is low gain as it provides high bandwidth. Therefore, I have designed the UWB antenna with MTM design to enhance the gain as well as the bandwidth. There is the distance between the UWB antenna and MTM structure is of 22.5mm as shown in the below fig 10.

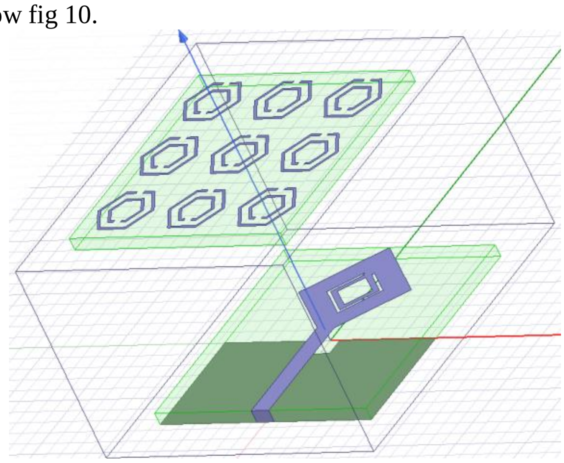

Figure 10: The UWB patch antenna design with MTM structure.

5. Comparison between Shapes of Metamaterial

The comparison study has been done between the different shapes of MTM to analyze the better shape of MTM design. First design which is shown in fig11. is made of a circular shape of MTM which is align with the patch antenna for simulation. Second design which is shown in fig 13. is of square shape MTM and the third design is of hexagonal shape as shown in fig.15.

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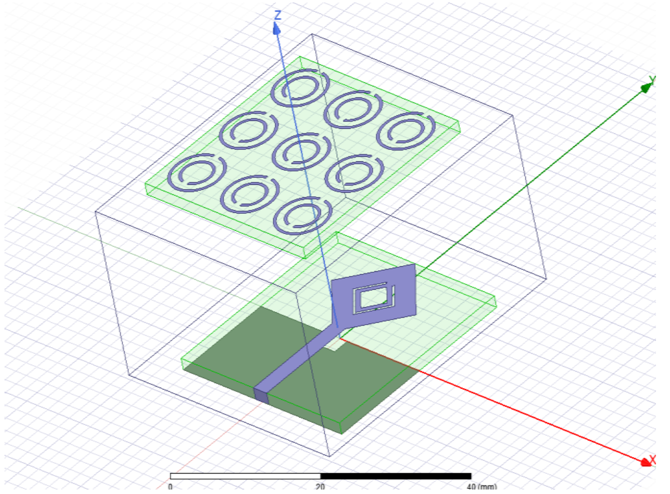

Figure 11: The design of UWB with circular shape MTM structure.

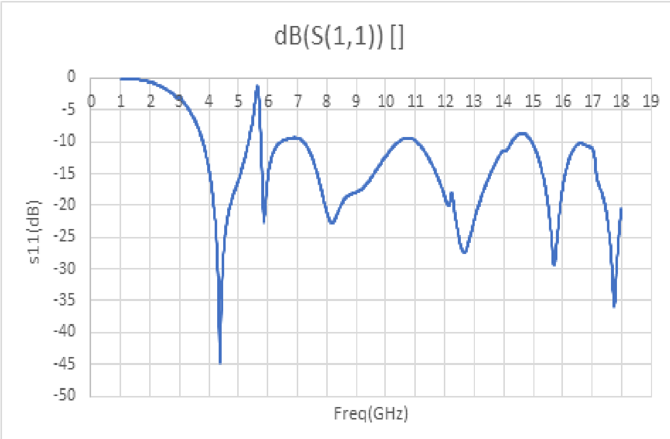

Figure 12: Simulated S parameters of circular MTM with highest return loss of - 45Db

After analyzing the result for S parameters of Rhombic UWB antenna without using the metamaterial to it, it is concluded that the antenna can works in the frequency range from 1GHz to 18GHz which is wideband range. So, by keeping the same design of rhombic UWB antenna and placing the circular shape metamaterial at distance of 22.5mm, the S parameters curve has been obtained. In the above figure 12, the highest peak of return loss is at - 45dB with bandwidth ratio of 4.7: 1 but having the rejection band at 5.3 - 5.8GHz.

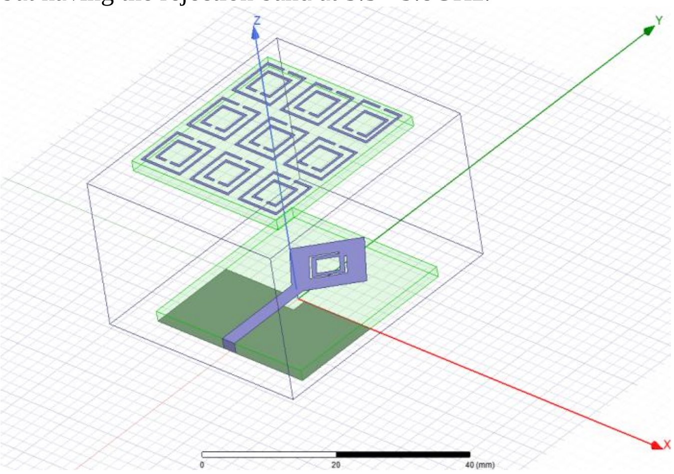

Figure 13: The design of UWB with square shape MTM structure.

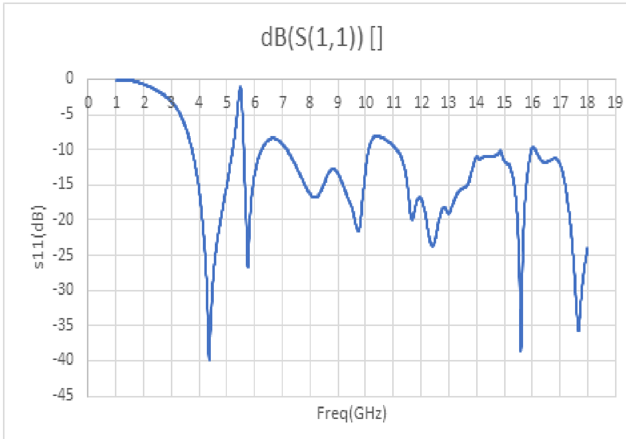

Figure 14: Simulated S parameters of Square MTM highest return loss of - 40dB

After checking the performance on S parameter of Circular shape metamaterial design antenna, now the result is shown below is of the Square shape design of metamaterial to analyze the performance over circular metamaterial structure. In the above figure 14, the highest peak of return loss is at - 40dB with bandwidth ratio of 5.1: 1 but having the rejection band at 5.2 - 5.6GHz. Here, in this design we could achieve the better bandwidth of antenna over the circular shape design.

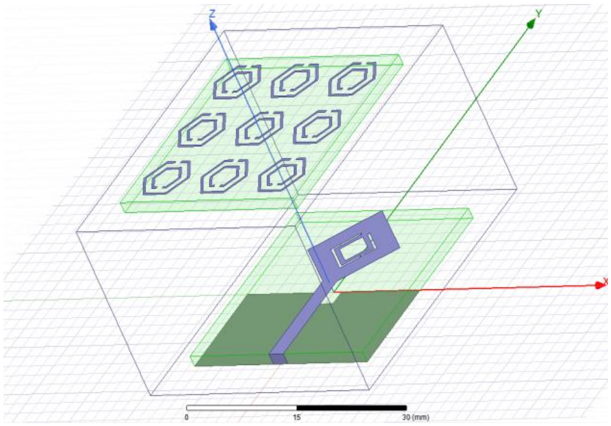

Figure 15: The design of UWB with hexagonal shape MTM structure.

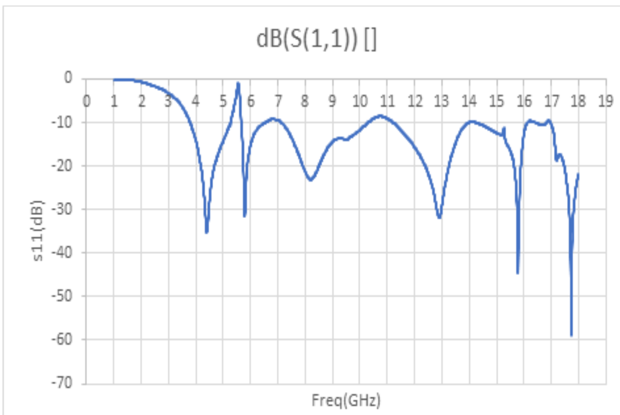

Figure 16: Simulated S parameters of hexagonal MTM highest return loss of - 58dB

Here, the third design result has been shown which is based on the hexagonal shape metamaterial design using the same rhombic antenna design. In the earlier both design using metamaterial the highest peak for the return loss was - 45dB and highest bandwidth ratio was 5: 1. In the above figure 16, the highest peak of return loss is at - 60dB with bandwidth ratio of 5.2: 1 but having the rejection band at 5.3 - 5.6GHz.

Table 1: Comparison between three different shapes of MTM with rhombic UWB antenna

Shapes of MTM	Circular	Square	Hexagonal
Return loss (dB)	- 45	- 39	- 40
Gain (dB)	4.7	5.8	5.85
Directivity (dB)	4.5	5.4	5.5
VSWR[at]4GHz	1.4	1.3	1.2

Table 2: Comparison between existing antenna and simulated rhombic UWB antenna

Designs	Bandwidth Range (GHz)	Highest Peak of Return Loss (dB)	Rejection Band (GHz)
UWB antenna without MTM	1 - 18	- 40	10 - 11
UWB antenna with Circular MTM	3.8 - 18	- 45	5.3 - 5.8
UWB antenna with Hexagonal MTM	3.5 - 18	- 58	5.3 - 5.8
UWB antenna with Square MTM	3.5 - 18	- 40	5.2 - 5.6
Existing UWB antenna	4 - 18	- 32	3.2 - 3.8

6. Conclusion

The above simulation result shows that the return loss of the antenna without MTM structures is 4.2dBi and gain of the antenna with MTM design is above 5dBi. So, it is been concluded that MTM structures has the good radiating effects as it has negative electromagnetic properties. Therefore, it gives better solution to our antenna when we add MTM structures to the antenna. The proposed antenna design with MTM has been simulated in HFSS and by doing the comparison between the different shapes of MTM, it is been concluded that hexagonal shape of MTM which has more curves than the circular shape has good result comparing to the other shapes. The proposed structure of the rhombic UHF antenna and MTM structure are stimulated and performance is verified using HFSS software tool.

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