A Wearable Monopole Antenna having Squared Slotted EBG Ground Structure for RF & Microwave Applications

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Abstract— A compact, low profile UWB antenna for Wireless Body Area Network (WBAN) is designed and simulated in this report. Using monopole compact with EBG structure, this antenna has been designed which behaves as a reflector. Later, the bevel is introduced on the monopole. These 3 evolutions are done to increase the bandwidth of our model. Later EBG cells are attached to get reflection and wide band response. It helps in impedance matching when the antenna is placed on the human for wearable applications

Keywords— Directional Antenna, EBG, WBAN, UWB

I. INTRODUCTION

WBAN is a developing field gaining much attention from the researchers due to its applications in everyday life to complex systems [1-5]. UWB antennas provides bandwidth coverage from 3.1-10.1 GHz along with high data rate with small power consumption.

There has been significant research and development in the field of compact monopole antennas in recent years [6-12]. Many researchers have focused on developing compact monopole antenna designs that are suitable for use in wearable and portable electronic devices, as well as other applications where size and weight are important considerations.

Some common approaches to designing compact monopole antennas include using a shorted feed line, a fractal geometry[13-16], or a complementary split ring resonator (CSRR) structure[17-21]. These techniques can be used to reduce the size of the antenna while still maintaining good performance characteristics, such as a wide bandwidth and high gain [22-27].

In addition to these design techniques, researchers have also investigated various ways to improve the performance of compact monopole antennas [28-32], such as by using different materials, shaping the antenna's geometry, or adding elements such as parasitic elements or reflectors.

Overall, the use of compact monopole antennas in wearable and portable electronic devices [33-38] has the potential to provide improved wireless communication capabilities in a small and lightweight form factor, which can be beneficial in a wide range of applications.

II. ANTENNA DESIGN

A compact monopole antenna having a slotted electromagnetic bandgap (EBG) ground structure is a type of antenna that has been designed for wearable RF applications. The compact monopole antenna is a small antenna that is easy to integrate into wearable devices, such as smartwatches or fitness trackers, due to its size and shape.

The fork slotted EBG structure is a type of structure that is used to improve the performance of the antenna [39, 40]. It is made up of a series of slots or gaps in a conducting surface, which can be used to reflect or absorb electromagnetic waves in a specific frequency range. When used as a backing for the compact monopole antenna, the EBG structure [41-44] can help to improve the antenna's radiation pattern, gain, and bandwidth, making it more suitable for wireless communication applications.

The ability to deliver increased performance in a small form factor is one potential benefit of adopting a compact monopole antenna coupled by slotted EBG ground structure in wearable applications. This can be especially useful in applications where size and weight are critical factors [45-48], such as in fitness trackers or other portable devices. Additionally, the EBG structure can help to reduce the antenna's sensitivity [49-51] to the presence of nearby objects or materials, which can be useful in wearable applications where the antenna is likely to be near the user's body [52-56].

The antenna is designed on a 0.2mm thick RO4003 substrate with a dielectric constant of 3.55 and loss tangent of 0.0027, the proposed antenna has an overall dimension of 20x25mm^2. The antenna is designed as Antenna 1 and modified over later to Antenna-2 and Antenna-3 to get the desired results according to the paper.

A. *Design and Evolution of Monopole Antenna*

Antenna-1 is the most basic design of our antenna model in which there is a monopole antenna attached to the square radiator and a partial ground plane of dimension 20x5 mm^2 on the backside of the substrate, which plays an important role in impedance matching. It should provide resonance covering 5-9 GHz,

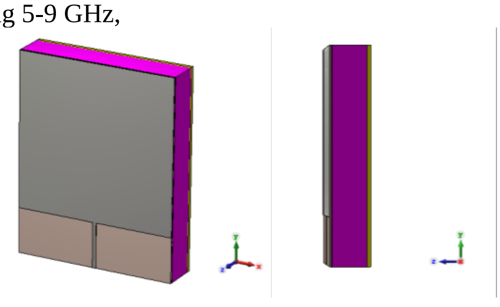


Figure 1:Antenna-1 Structure

Antenna-2 is designed by modifying our basic antenna. The square radiator is cut in a way that we obtain a triangular like structure at the bottom [57, 58]. This truncated modification is used for bandwidth enhancement. It should provide resonance covering 4.5-10 GHz.

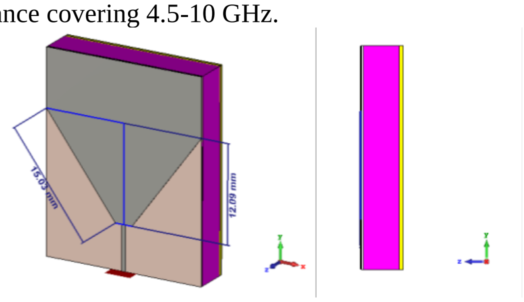


Figure 2: Antenna-2 Structure

Antenna-3 is the modification of our antenna 2 in which the area near the conductor is shaped into beveled edges to achieve the resonance at 10 GHz in order to provide a bandwidth of 3.1-10 GHz. Increasing the radiating element's electrical length improves the low frequency response.

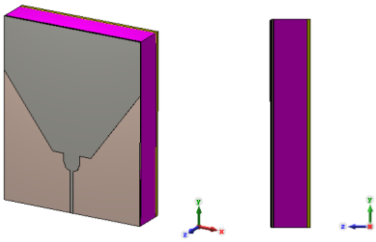


Figure 3: Antenna-3 Structure

III. DESIGNING OF EBG

The proposed solution should give a omnidirectional radiation pattern. The consequences of impedance mismatch, frequency detuning, and back radiation occur when the antenna is positioned on the human body. EBG cells are created to function as reflectors and are positioned atop a foam sheet in order to get around this. It improves the bandwidth, gain, and efficiency of our model rather than affecting its performance.

A MATLAB script was used to calculate the scaling factors. As the lengths of our actual sheet is 8x8 mm^2 and the lengths predefined by Photoshop (Figure 5) were 342.55x

```
Sh=274.11/8; %scale factor of y-axis(height)
Sw=342.55/8; %scale factor of x-axis (length)

c=38.6/Sh;
d=33.9/Sh;
c1=41.8/Sh;
d1=86.2/Sw;
e=51.3/Sw;
```

Figure 4: MATLAB script used to calculate the dimensions of EBG Cells

These parameters were used for design. But they were also optimized according to the best fit results.

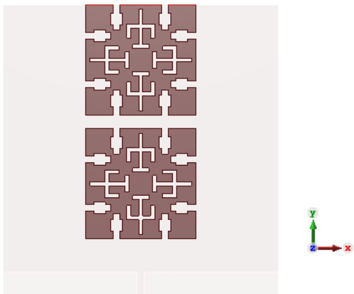


Figure54: EBG Cells Model on CST

According to the calculations it should provide a dual band stop response centered at 6.25 to 8.1 GHz. The dimensions of the fork and slits are adjusted in such a way to get our wide band gap response in 4.5 GHz to 10.1 GHz due to the additional capacitance effect.

IV. FUNCTION OF FOAM LAYER AND METAL SHEET

A foam layer is introduced in our model which is directly sandwiched between the EBG layer and the metallic sheet. The thickness of the foam layer is 4mm while the thickness of the metallic sheet is 0.2mm

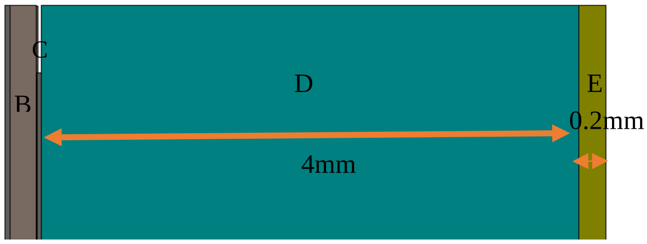


Figure 6: Layers of antenna. (A)PEC radiator (B)Rogers 4003C Substrate (C)PEC ground (D)Foam layer (E) Copper (annealed) metallic layer

The material of the foam is layer is defined as material 1, several models were tried from the CST material library.

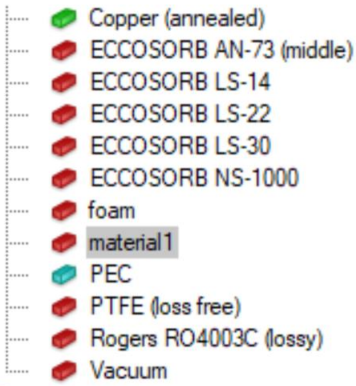


Figure 7: Materials used for Foam- ECCOSORB series, PTFE and LAST-A-FOAM series.

V. SIMULATION RESULTS AND DISCUSSION

The method of suspended transmission line (MoSTL) is being used in the designing of the EBG cells. In which, the EBG must be connected to the ground plane via a conductor method. I defined the port as follows:

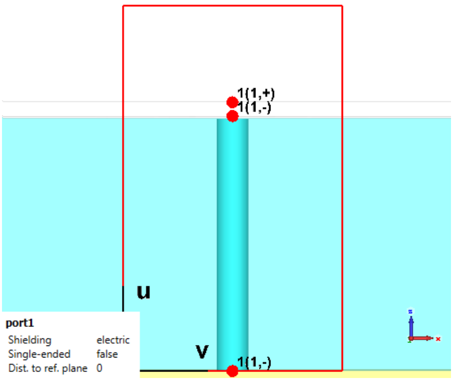


Figure 8: Transmission line port definition method using the Multipin port option

Where the transmission line is given the positive charge. The ground plane and the metal sheet are assigned negative polarity.

It is essential in MoSTL that the EBG is connected to the ground by installing vias. We have used a cylinder of radius 0.25mm to connect the EBG cell with the metal sheet.

Firstly, the base line results are obtained by only simulating the antenna part without EBG, foam and metal layers.

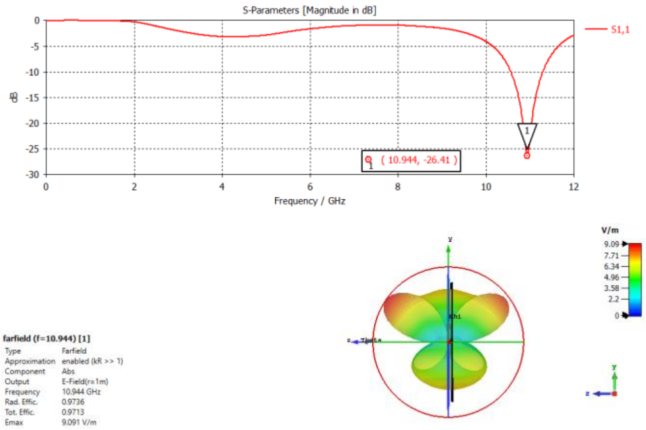


Figure 9: Antenna 1 s-parameters and Farfield, baseline model

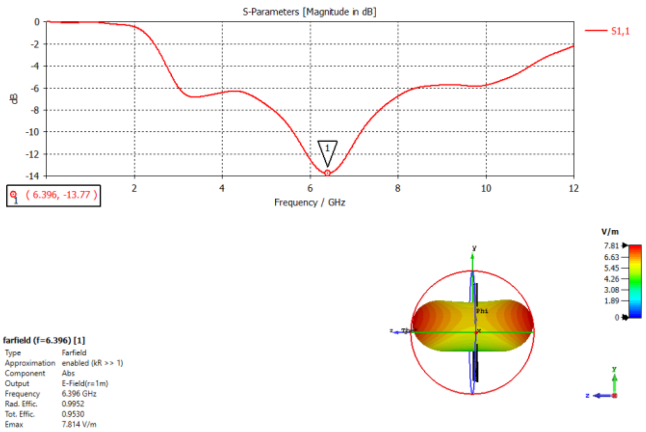


Figure 10: Antenna 2 s-parameters and Farfield, baseline model

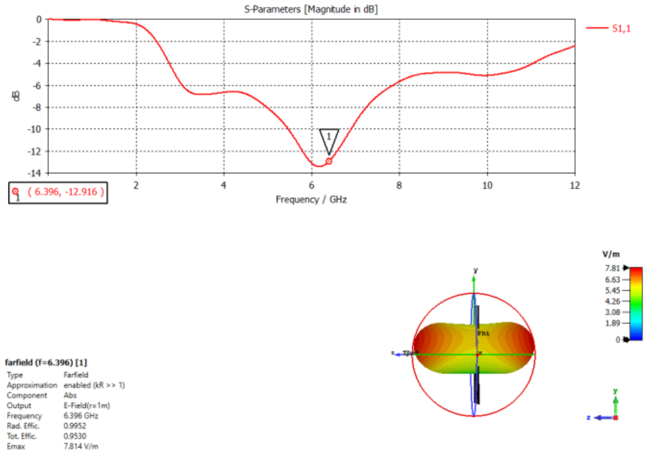


Figure 11: Antenna 3 s-parameters and Farfield, baseline model

The reference impedance of the all the models were 47 Ohms.

The VSWR were

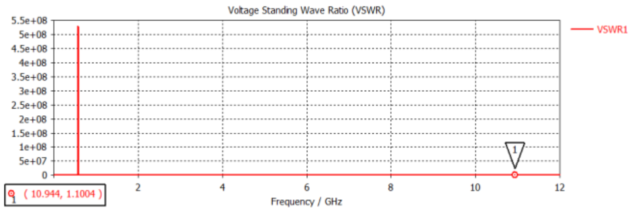


Figure 12: Antenna 1 baseline, VSWR

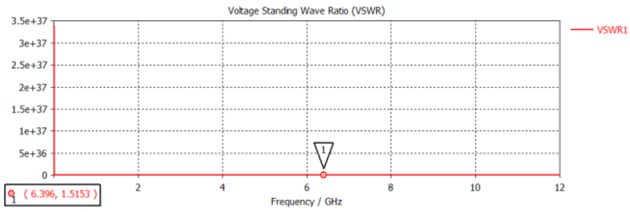


Figure 13: Antenna 2 baseline, VSWR

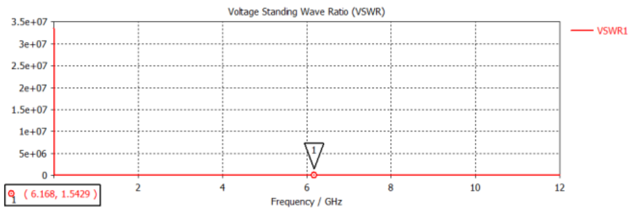
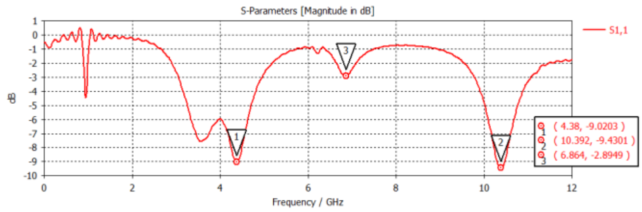


Figure 14: Antenna 3 baseline, VSWR

A. *Final Models:*



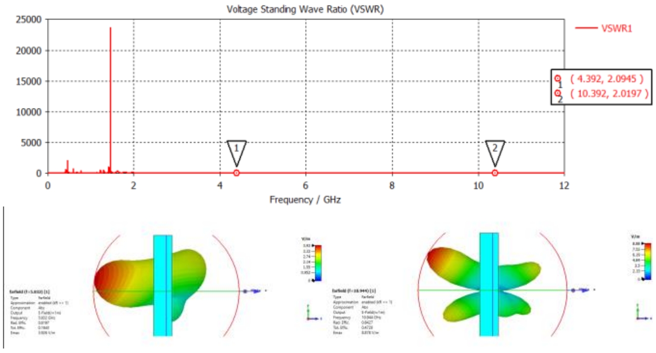


Figure 15: Antenna 1, Results

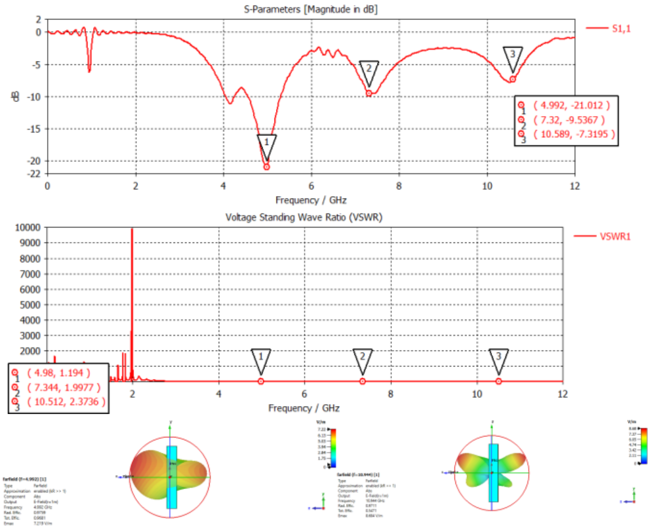


Figure 5: Antenna 2, Results

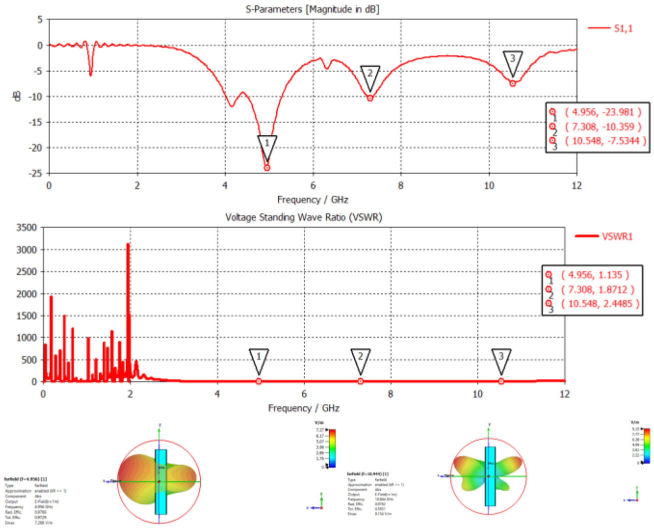


Figure 17: Antenna 3, Results

It can be seen that in every evolution the bandwidth is obtained is near to -10dB in the graph, but not exactly below -10dB. This is due to the unknown foam material and the reflection is not good enough in this case as the far fields are depicting due to the inaccurate dimension of the EBG cells

VI. CONCLUSION

The model was drawn up to scale in CST studio 2020 in which the return loss is achieved near to desired and it is which is quite promising as per calculations. Return loss and far field patterns of all three designs are depicted in this article. EBG dimension and MoSTL method used along the EBG cells, which is beyond our scope but achieved perfectly.

VII. REFRENCES

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