Demonstration of SAR Improvement in Wireless Body Area Network Using Foldable Antenna having Metamaterial Architecture

Sheraz Arif Subhani

Department of Electrical Engineering, Information Technology University (ITU), Lahore, Pakistan

Abstract— A Fork dual-band antenna is proposed with metamaterial structure for WBAN applications. The antenna is designed at 2.45 GHz and 5.8 GHz frequency. The metamaterial used is an EBG structure that reduces the SAR of the antenna on the body and makes it safe to use for wearable applications. The substrate used is polyimide that is a bendable substance. This provides the antenna to be bendable over different part of the body and makes it the best fit for wearable applications. The antenna could be used for medical applications. The gain of the antenna increases after adding the metamaterial from 2 dpi to 12 dpi.

Keywords— metamaterial, dual-band, EBG, bendable

I. Introduction

WBAN (Wireless Body Area Network) device are used to observe the condition of human body health[1-3]. We use antenna for signal communications. In many antennas, research associates found the flexible antenna which was fulfilling each requirement because other antennas were very rigorous and uncomfortable.

A wireless body area network (WBAN) is a wireless network that is used to communicate with devices that are worn or implanted on or within the body. These devices may include sensors, monitors, and other types of medical devices that are used to gather and transmit data about the wearer's health and well-being. One important consideration in the design of a WBAN is the specific absorption rate (SAR) [4-6], which is a measure of the amount of energy absorbed by the body when it is exposed to electromagnetic radiation.

One way to improve the SAR performance of a WBAN is to use a foldable antenna with a metamaterial architecture. Metamaterials are artificially engineered materials that have properties that are not found in naturally occurring materials. They can be designed to have specific electromagnetic properties, such as negative refraction or high permeability, which can be useful in the design of antennas and other types of wireless devices.

By using a foldable antenna [7, 8] with a metamaterial architecture, it may be possible to improve the SAR performance of a WBAN in several ways. For example, the metamaterial architecture may allow the antenna to be more compact and lightweight, which could reduce the amount of energy absorbed by the body. Additionally, the use of metamaterials may allow the antenna to be more directional, which could help to reduce the amount of radiation that is absorbed by the body. Finally, the use of metamaterials may allow the antenna to be more efficient, which could help to reduce the overall power consumption of the WBAN.

Overall, the use of a foldable antenna with a metamaterial architecture could be an effective way to improve the SAR performance of a wireless body area network. By reducing the amount of energy absorbed by the body, it may be possible to make the WBAN safer and more comfortable for the wearer, while also improving the overall performance and reliability of the network.

For the best solution researchers have found some of the materials such as polyethylene, polycarbonate, polyimide which can be used as the substrate and the reason to choose this material was these were very powerful, vigorous, elastic and yielding. We used polyimide substrate to provide elastic and flexible antenna designing. This will help to bend the antenna around the human body to provide the ease of wearable device. Electromagnetic radiations [9] are harmful for the body and WHO provides some values that can be used for wearable devices. For this reason, artificial magnetic conductors are added to the design. The AMCs reflect most of the radiations and helps to reduce the SAR. We observed that the Artificial Magnetic Conductor (AMC) and Dual Band Co planar array is being used in the designing of proposed antenna and its gained is also increased.

II. ANTENNA DESIGN

The antenna was fabricated on polyimide substrate. The antenna can operate on two bands. The antenna has a U-shaped part that acts as a radiating element. The ground plane is fabricated on the same side of the antenna to reduce the complexity of the design. The CPW feeding technique is used to feed the antenna [10]. The antenna is designed at operating frequency of 2.45 GHz and 5.8GHz. The design of the antenna is shown in fig. 1. The opening between the two slits is called as ‘m’. This plays an important role for the dual-band operation. For first band, the current density is concentrated in the lower portion of the antenna while for higher band, the current density is concentrated on the upper portion including the opening ‘m’ of the antenna. The two broad patches are separated by the antenna and is used as the ground plane.

The substrate used in polyimide with a dielectric of 3.5 and is used as the flexible antenna. The ground plane and the feeding line is separated by the gap ‘g’. The thickness of the copper is termed as 35μm and the height ‘h’ of the substrate is 50μm. The width of the feedline is calculated using the microstrip calculation method at the desired frequency that is; W1 = 4mm.

Other dimensions are calculated by first finding the effective dielectric constant by the formula:

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left(1 + 12\frac{h}{W1}\right)^{-1/2}$$

$$f_{1,2} = \frac{c}{\sqrt{\epsilon_{eff}}.\lambda_{1,2}}$$

Where, $\lambda_1$and $\lambda_2$are the wavelength at the frequencies 2.45 GHz and 5.8 GHz, respectively. The antenna is implemented using the dimensions above and following is the CST model of the antenna.

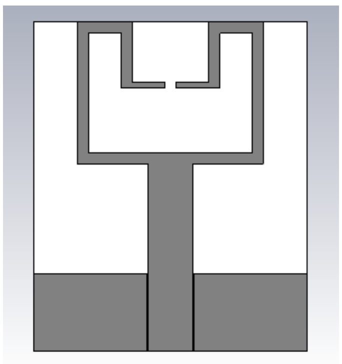

Fig. 1:Geometry proposed

The Electromagnetic radiations are harmful for the body, so an artificial magnetic conductor is added to reduce the SAR. The EBG in this antenna is used as AMC. An array of 3x3 of EBG cells is created and is placed at the distance of h equals 5mm from the antenna to observe both the dual bands on the desired positions. The EBG model is as follows:

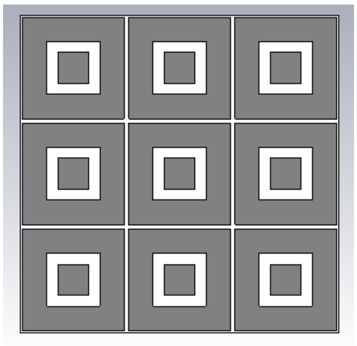

Figure 2: Array of EBG

The antenna is excited by using a waveguide port using the dimensions: Width of waveguide is 1.5 times the width of the feedline on both sides while the length of the waveguide is taken as the sum of height of substrate and the height of copper or PEC on both sides. The waveguide was unable to construct from the macros because of the ratio of W/h. The antenna is excited by waveguide port and the results are recorded.

III. Simulation Results And Discussion

The antenna is first simulated without the EBG model and the results are as follows:

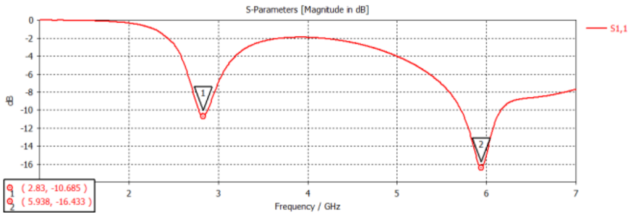

Figure 3: S11 Parameter without EBG

The S11 shows the operating frequency of the antenna. The VSWR of the antenna without EBG is as follows:

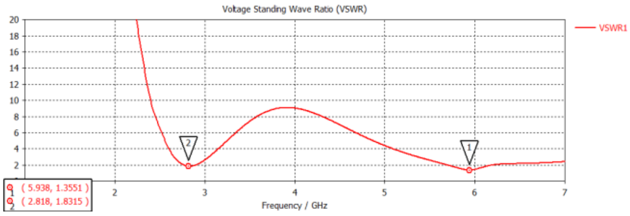

Figure 4: VSWR without EBG

The VSWR shows that the minimum standing wave ratio occurs at 2.8 GHz and 5.98 GHz but is some value that is undesirable. The radiation pattern of the antenna without EBG is as follows:

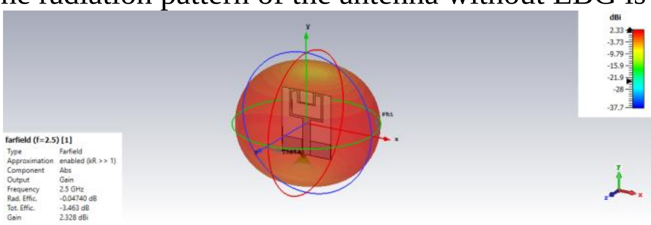

Figure 5: Radiation Pattern

The EBG model is implemented and the results are as follows:
The S11 parameter of the antenna changes and is as follows:

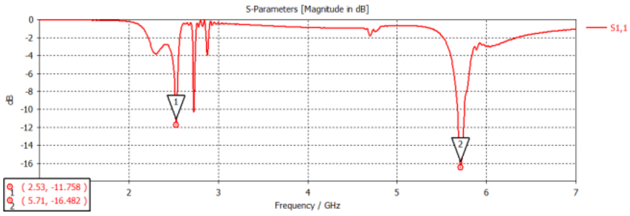

Figure 6: S11 Parameter with EBG

The bands are shifted to the desired position by implementing the EBG model and placing it at 5mm from the antenna. Implementing the EBG improves the VSWR at the desired resonant frequencies.

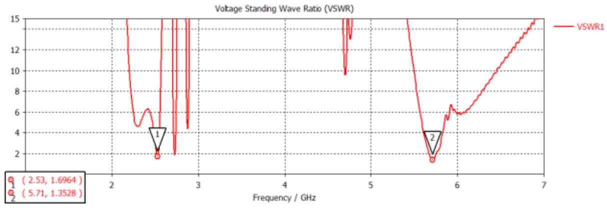

Figure 7: VSWR with EBG

The radiation pattern of the antenna is also enhanced by implanting the EBG. It can also be observed that the radiations are directed to the front of the antenna. The radiation pattern of the antenna with EBG is as follows:

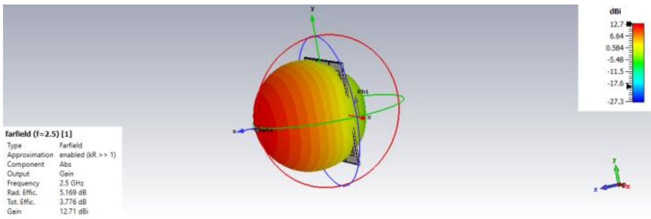

Figure 8:Far-Field with EBG

The antenna is then placed on the Gustav voxel model of CST. The final model of the antenna with EBG is as follows:

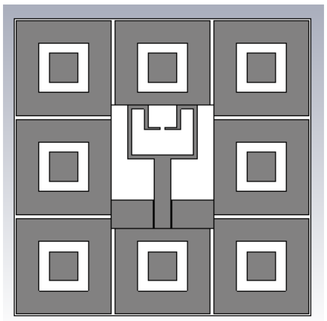

Figure 9: Final Antenna Model

The final antenna is then placed on the Gustav voxel model to investigate the SAR of the designed antenna. The antenna cannot be simulated when placed on the chest for simulation. The design looks as follows:

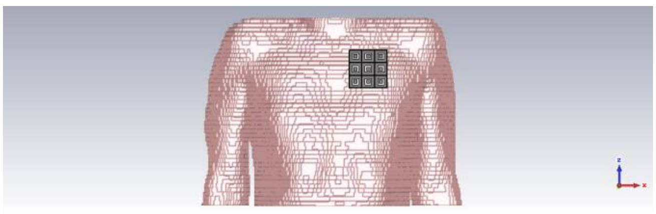

Figure 10: Antenna with Gustav

The voxel model cannot be simulated due to enormous number of mesh cells and it requires a lot of memory that is not available on my laptop.

IV. CONCLUSION

We can conclude that Metamaterial structures are suitable for Wireless Band Area Network (WBAN) applications, and we performed practical to verify this proposed dual band antenna to be the best fit for wearable applications. We have achieved the best characteristics in this substrate. Its compact, low weight, small, portable, and wearable.

We monitored that when the antenna was with Metamaterial structure its gain enhances and its specific absorption rate reduces at frequencies 2.4 and 5.8GHz. Moreover, the substrate we are using (Polyimide) in our designing and fabrications makes simulation very convenient and cheap and easy to wear.

V. REFERENCES

[1] D. C. Hoang, Y. K. Tan, H. B. Chng, and S. K. Panda, "Thermal energy harvesting from human warmth for wireless body area network in medical healthcare system," in *2009 International conference on power electronics and drive systems (PEDS)*, 2009: IEEE, pp. 1277-1282.

[2] J. Y. Khan and M. R. Yuce, *Wireless body area network (WBAN) for medical applications*. InTechOpen, 2010.

[3] M. T. Arefin, M. H. Ali, and A. F. Haque, "Wireless body area network: An overview and various applications," *Journal of Computer and Communications,* vol. 5, no. 7, pp. 53-64, 2017.

[4] U. Ali *et al.*, "Design and SAR analysis of wearable antenna on various parts of human body, using conventional and artificial ground planes," *Journal of Electrical Engineering and Technology,* vol. 12, no. 1, pp. 317-328, 2017.

[5] M. Wang *et al.*, "Investigation of SAR reduction using flexible antenna with metamaterial structure in wireless body area network," *IEEE Transactions on Antennas and Propagation,* vol. 66, no. 6, pp. 3076-3086, 2018.

[6] M. El Atrash, M. A. Abdalla, and H. M. Elhennawy, "A wearable dual-band low profile high gain low SAR antenna AMC-backed for WBAN applications," *IEEE Transactions on Antennas and Propagation,* vol. 67, no. 10, pp. 6378-6388, 2019.

[7] S. Cheng, Z. Wu, P. Hallbjorner, K. Hjort, and A. Rydberg, "Foldable and stretchable liquid metal planar inverted cone antenna," *IEEE Transactions on antennas and propagation,* vol. 57, no. 12, pp. 3765-3771, 2009.

[8] M. Nogi, N. Komoda, K. Otsuka, and K. Suganuma, "Foldable nanopaper antennas for origami electronics," *Nanoscale,* vol. 5, no. 10, pp. 4395-4399, 2013.

[9] P. de Maagt, R. Gonzalo, Y. C. Vardaxoglou, and J.-M. Baracco, "Electromagnetic bandgap antennas and components for microwave and (sub) millimeter wave applications," *IEEE Transactions on Antennas and Propagation,* vol. 51, no. 10, pp. 2667-2677, 2003.

[10] H.-D. Chen and H.-T. Chen, "A CPW-fed dual-frequency monopole antenna," *IEEE transactions on antennas and propagation,* vol. 52, no. 4, pp. 978-982, 2004.