

2.45 GHz wearable rectenna array design for microwave energy harvesting

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ABSTRACT

This paper presents a design of a wearable textile microstrip patch rectifying antenna (rectenna) array operating for Wireless Body Area Network (WBAN) at the center frequency, f_c of 2.45 GHz. Precisely, jeans or denim with the relative permittivity, $\epsilon_r = 1.70$ and thickness of 1.00 mm is chosen as a substrate attached to ShieldIt Super as a conductive material with the thickness, h of 0.17 mm and conductivity of 6.67×10^5 S/m, respectively. In the first stage, a microstrip patch antenna array layout with the inset fed technique is designed and simulated by using the Keysight Advanced Design System (ADS) software. In the second stage, a wearable textile microstrip patch antenna array is fabricated, integrated, and hidden inside the jeans fabric. In the third stage, the rectifier circuit layout on the Flame Retardant-4 (FR-4) Printed Circuit Board (PCB) with the dielectric constant, $\epsilon_r = 4.7$, thickness, $h = 1.6$ mm, and loss tangent, $\delta = 0.018$ that can generate Radio Frequency-Direct Current (RF-DC) conversion is designed and simulated using the ADS software. Each simulation result and fabrication measurement shows that the designed antenna array characteristics are suitable for an Industrial, Scientific, and Medical radio (ISM) band by having the reflection coefficient, S_{11} less than -10 decibel (dB) at the respective resonant frequency, f_r . Moreover, through simulation, the output DC voltage for the bridge rectifier circuit is from 132 mV to 5.01 V with the corresponding Power Conversion Efficiency (PCE) between 3.48% and 50.20% whereas for the voltage doubler rectifier, the output DC voltage is from 417 mV to 2.91 V with the corresponding PCE between 34.78% and 53.56%, respectively.

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1. INTRODUCTION

Nowadays, Wireless Body Area Network (WBAN) plays important role in linking various electronic devices in and on the human body. The application of WBAN has been intensifying in various fields including medical, military, navigation, entertainment, and sport. Several frequency bands have been assigned for WBAN systems known as the Medical Implant Communication System band (MICS: 400 MHz), the Industrial Scientific Medical band (ISM: 2.40 GHz and 5.80 GHz), and the Ultra-Wide Band (UWB: 3.00-10.00 GHz), respectively [1].

In order to support the WBAN, many research efforts being focused on wearable antenna development. Precisely, wearable antennas are becoming more and more lightweight that can be integrated

into or hidden inside clothing [2] or attached to clothing e.g. jacket to improve wireless communication links [3]. In this case, a microstrip antenna with a textile material as a substrate, which is flexible, low profile, and small size is considered to be more suitable for WBAN antenna design [4]. Moreover, fabrics including textile are particularly relevant for wearables due to their broad acceptance and low cost [5].

Wearable electronics generally are powered by a battery system, which require frequent charging. However, power supply sometimes is not easily available to charge these electronic devices. Hence, it becomes as a significant setback for users. This problem can be overcome by applying energy harvesting techniques, which capture energy from available natural sources, such as solar, wind, thermal, microwave and Radio Frequency (RF) energy to be as the alternative power source [6]. RF can be as an alternative energy sources since it does not require exposure to heat or wind, and can be moved freely within the range of the transmission source [7]. Precisely, in rectenna design, the main function of the rectifier circuit is converting the captured RF energy to Direct Current (DC) with minimum loss and supplying the DC to wearable electronic devices. In other words, rectenna will not only be deployed to transmit and receive RF and microwave signal for communications but also for powering and charging low-power electronic devices, such as sensors [8]. In this case, the antenna should receive an adequate amount of power or RF energy to increase Power Conversion Efficiency (PCE) in the rectifier circuit [9].

2. ANTENNA STRUCTURE AND DESIGN

2.1. Types of Textile Material

ShieldIt Super is a rugged rip-stop fabric manufactured by LessEM Incorporated, USA basically deployed as the antenna conductive element and ground plane [10]. ShieldIt Super has a weight, w of 230 g/m², a thickness, t , of 0.17 mm, conductivity of 6.67×10^5 S/m and a surface resistivity, R_s less than 0.5 Ω /sq. This study chooses ShieldIt Super as the conductive textile because it has an adhesive backing that can be easily attached to a substrate by using clothes iron. Furthermore, it has a good conductivity or low resistivity, less corrosion, and more hydrophobic [11]. In this study, jeans fabric is used as the substrate material since it is cheap, lightweight, and flexible. The jeans fabric has the thickness, h of 1.00 mm, dielectric constant or relative permittivity, ϵ_r of 1.716, and dissipation factor or loss tangent, $\tan \delta$ of 0.025, respectively [12]. By having the $\epsilon_r < 2.00$, the wearable microstrip patch antenna can produce an acceptable efficiency and a high gain [2]. Table 1 show the specifications of textile materials used as the conductive and substrate in this study. Microstrip Patch Antenna Structure as shown in Figure 1.

Table 1. Specifications of Textile Material

Material Type	Thickness (mm)	Permittivity (ϵ_r)	Conductivity (S/m)
Jeans Fabric	1.00	1.716	-
ShieldIt Super	0.17	-	6.67×10^5

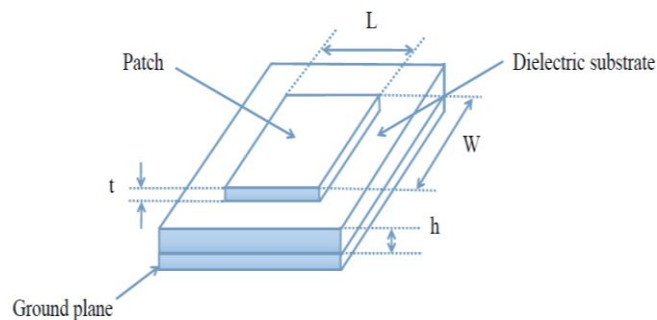


Figure 1. Microstrip patch antenna structure

2.2. Patch Antenna Design

A. Calculation of Microstrip Patch Antenna

Figure 1 shows the rectangular microstrip patch antenna structure consists of conductive, substrate and ground planes. The patch size is generally dependent upon the resonant frequency, f_r and substrate dielectric constant, ϵ_r [13]. The f_r is the center frequency, $f_c = 2.45$ GHz where the width of the patch, W is calculated using (1):

$$W = \frac{c}{2f_r \left(\sqrt{\frac{\epsilon_r + 1}{2}} \right)} \tag{1}$$

According to (1), c is the speed of light where the increment of ϵ_r will decrease the size of the antenna patch. The actual length of the patch is computed as in (2):

$$L = \frac{c}{2f_r \sqrt{\epsilon_{reff}}} - 2\Delta L \tag{2}$$

Based on (2), the effective dielectric constant, ϵ_{reff} is defined as in (3):

$$\epsilon_{reff} = \left(\frac{\epsilon_r + 1}{2} \right) + \left(\frac{\epsilon_r - 1}{2} \right) + \left(1 + \frac{12h}{W} \right)^{-\frac{1}{2}} \tag{3}$$

Moreover, the length extension, ΔL is calculated as shown in (4) below:

$$\Delta L = 0.412h \left[\frac{(\epsilon_{reff} + 0.3)}{(\epsilon_{reff} - 0.258)} \right] \left[\frac{\left(\frac{W}{h} + 0.264 \right)}{\left(\frac{W}{h} + 0.8 \right)} \right] \tag{4}$$

Due to fringing, the size of antenna is increased by an amount of ΔL . Thus, the actual length, L of the patch can be calculated as follow:

$$L = \frac{c}{2f \sqrt{\epsilon_{reff}}} - 2\Delta \tag{5}$$

B. Calculation of the Antenna Ground Plane

The length and width of the substrate is equal to that of the ground plane. Therefore, the length of ground, l_g and width of the ground, W_g are calculated using (6) and (7):

$$l_g = 6h + l \tag{6}$$

$$W_g = 6h + W \tag{7}$$

C. Calculation of Microstrip Line Feed

Then, the microstrip synthesis, H with characteristic impedance, Z_0 equals to 50Ω is calculated using (8):

$$H = \left[\frac{Z_0 \sqrt{2(\epsilon_r + 1)}}{119.9} \right] + \frac{1}{2} \left[\frac{\epsilon_r - 1}{\epsilon_r + 1} \right] \left[\ln \left(\frac{\pi}{2} \right) + \frac{1}{\epsilon_r} \ln \left(\frac{4}{\pi} \right) \right] \tag{8}$$

Based on (8), the width of microstrip line feed, W_f is computed deploying (9):

$$W_f = \left[\left(\frac{e^H}{8} - \frac{1}{4e^H} \right)^{-1} \right] \times 1.6 \text{ mm} \tag{9}$$

Furthermore, the length of microstrip line feed, L_f is obtained through (10):

$$L_f = \theta \times \frac{\lambda_g}{360^\circ} \tag{10}$$

where,

$$\lambda_g = \frac{c}{f \sqrt{\epsilon_{reff}}} \tag{11}$$

The design of the wearable microstrip patch antenna schematic and layout is made using the Keysight Advanced Design System (ADS) software based on the microstrip patch antenna, ground dimension, and line feed values through calculations using (1) - (11).

In this study, the edge inset-feeding technique is applied on a microstrip patch. Compared to other direct contact and non-contact microstrip feeding technique, the inset-fed technique has an advantage in a

power distribution scheme that is easy to be fabricated. Hence, the inset-fed network and radiating patches will be etched on the same conductive textile material, which is the ShieldIt Super.

Figure 2 shows the schematic design of the microstrip patch antenna in the first stage using the ADS microstrip line (MLIN), microstrip line open-circuited stub (MLOC), and microstrip asymmetric coupled line (MACLIN). The MACLIN is added in the design to create the inset-fed line. In this case, width 1, W_1 and width 3, W_3 are equal and calculated based on the width of the substrate, W as in (12):

$$W_1 = W_3 = \frac{W-9}{2} \tag{12}$$

On the other hand, the width 2, W_2 is equal to the width of microstrip line feed, W_f as in (9). Moreover, S_1 and S_2 are the gaps of the inset-fed where both are equal to W_f .

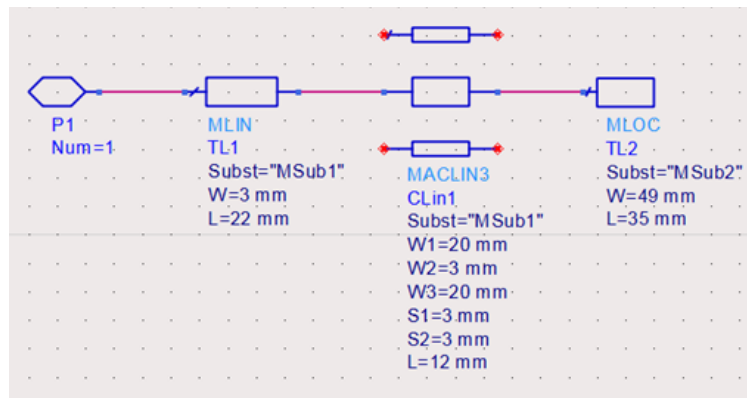


Figure 2. Microstrip patch antenna schematic design

Figure 3 shows the designed inset-fed microstrip patch antenna parameters, which are recalculated after some troubleshooting processes using the Keysight ADS software to achieve the resonant at $f_c = 2.45$ GHz and simulated return loss, S_{11} less than -10 decibel (dB), respectively. It is assumed that the input impedance is 50Ω , the width of microstrip feed line, W_f , the length of inset, F_i and the gap between the patch and the inset-fed line, G_{pf} , respectively. Figure 4 shows the respective layout of the designed patch antenna using the inset-fed edge technique.

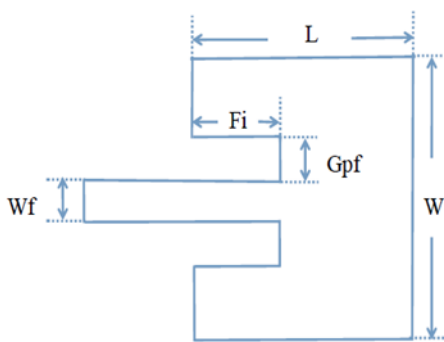


Figure 3. Inset-Fed line parameters

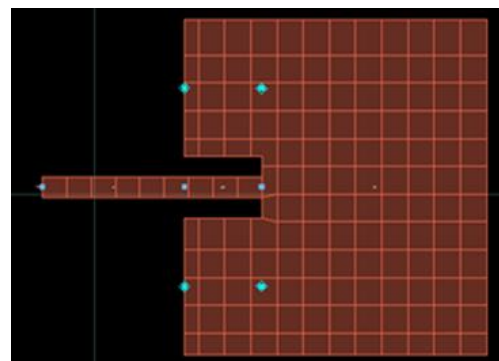


Figure 4. Microstrip patch antenna layout design

In the next stage, the microstrip patch antenna array is designed using the ADS microstrip curve (MCURVE) and microstrip T-junction (MTEE). The schematic and layout design of the microstrip patch antenna array are shown in Figure 5 and Figure 6, respectively.

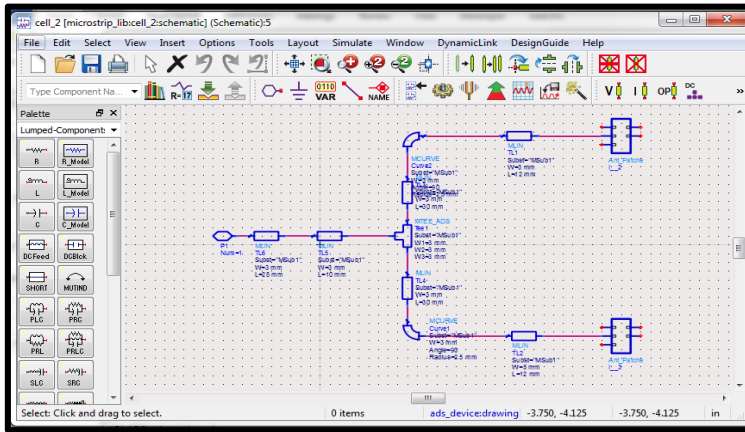


Figure 5. Microstrip patch antenna array schematic design

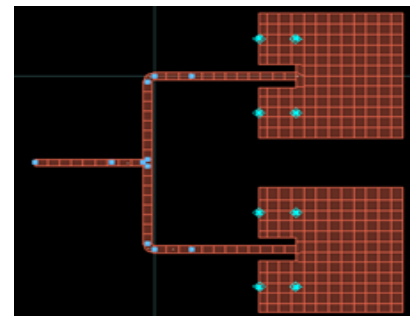


Figure 6. Microstrip patch antenna array layout design

Afterwards, the microstrip patch antenna array is fabricated where the ShieldIt Super as a textile conductive is attached to the jeans fabric as a textile substrate using clothes iron. The wearable textile microstrip patch antenna array is then soldered with a 50 Ω impedance SubMiniature version A (SMA) probe connector so that the antenna can be connected to a Vector Network Analyzer (VNA) via a Radio Frequency (RF) coaxial cable for performance measurements. Figure 7 shows the fabricated inset-fed textile microstrip patch antenna array.

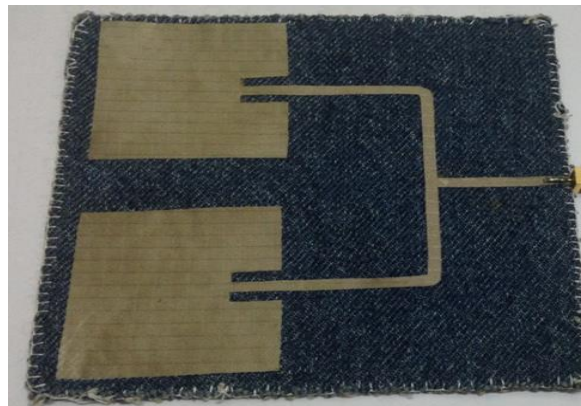


Figure 7. Wearable textile microstrip patch antenna array fabrication

2.3. Rectifier Circuit Design

In this project, the RF-DC conversion system is designed using the bridge rectifier and voltage doubler. The receiving antenna for the energy harvesting system is designed to be operated at 2.45 GHz with the output impedance of 50 Ω. Therefore, the input impedance of the rectifier is designed to match the output impedance to maximize the power transfer and to minimize the signal reflection from the load. Figure 8 and Figure 9 shows the schematic design of the bridge rectifier circuit and the voltage doubler, respectively. The rectifier circuit is constructed using four HSMS-8101 microwave Schottky diodes that form a bridge. As for the voltage doubler, two HSMS-2852 zero bias Schottky detector diodes are used. The Schottky diode is chosen because it has a low turn on voltage between 0.2 V and 0.3 V, high detection sensitivity up to 35 mV/μW at 2.45 GHz and can operate at high frequencies up to 5.8 GHz compared to PN junction diode.

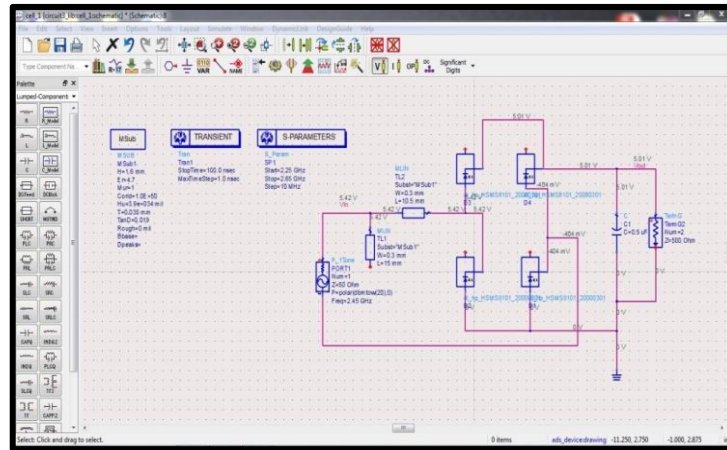


Figure 8. Bridge rectifier circuit schematic design

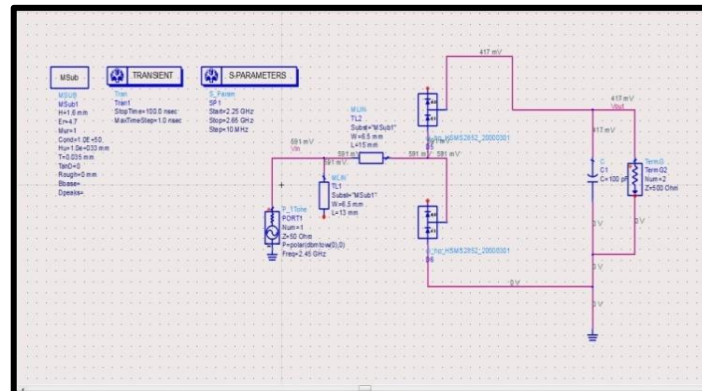


Figure 9. Voltage doubler schematic design

The following equation shows the input impedance, Z_{in} of the bridge rectifier and the impedance matching is designed by adding two microstrip lines in the T-network.

$$Z_{in} = \frac{R_L + 2R_{diode}}{2} \tag{13}$$

where,

Z_{in} = Input impedance

R_L = Load resistance = 500 Ω

R_{diode} = Dynamic resistance of diode = 9.64 Ω

3. RESULT AND DISCUSSION

In this section, both simulation and actual measurements of the inset-fed microstrip patch antenna array performance in the free space is discussed. The simulation is performed by using the Keysight Advanced Design System (ADS) software whereas the measurement is done using the Keysight E5071C Vector Network Analyzer (VNA). The antenna performance is simulated and measured precisely in terms of return loss or S_{11} parameter, gain, directivity and efficiency, and Three-Dimensional (3D) radiation pattern.

S_{11} in an antenna is a parameter that states the total of power that is lost or delivered to the load and does not return as a reflection. Ideally, the antenna should achieve the S_{11} of the antenna lower than -10 dB to obtain a good performance [2]. Figure 10 depicts the simulation of S_{11} parameter in terms of magnitude in decibel (dB) and phase in degree of the designed textile microstrip patch antenna array. Based on the ADS software simulation, the microstrip patch antenna array located on the free space has the linearly fitted S_{11} parameter of -16.962 dB at the resonant frequency, $f_r = 2.437$ GHz.

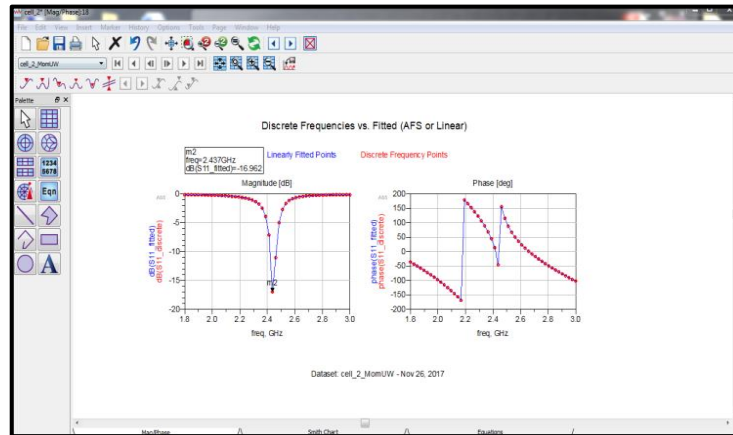


Figure 10. Microstrip patch antenna array return loss simulation

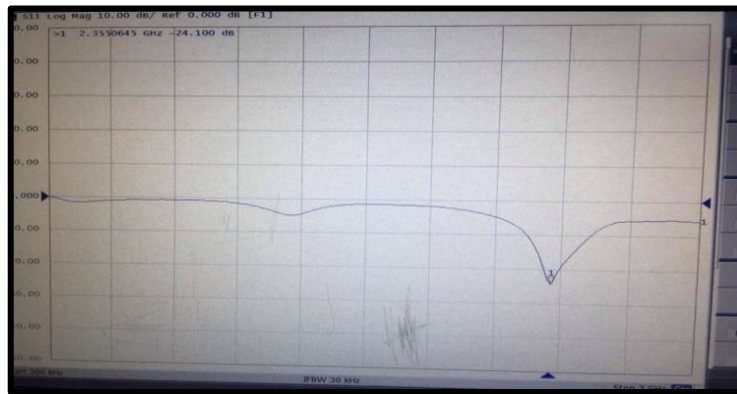


Figure 11. Microstrip patch antenna array return loss measurement

Figure 11 shows the S_{11} measurement on the fabricated textile microstrip patch antenna array, which is -24.10 dB at the f_r of around 2.355 GHz. This is better than the single element of microstrip patch antenna using jeans as the substrate fabric and ShieldIt Super used as the conductive textile with S_{11} of -15.522 dB at the f_r of 2.24 GHz [14]. This result is comparable with jeans used as the substrate textile and WECF adhesive copper sheet used as the conductive metal in [12], which has S_{11} of -13.66 dB at the f_r of 1.59 GHz and also comparable with the Cuming Microwave C-Foam PF-4 foam used as the substrate and the silver-coated nylon rip-stop fabric used as the textile conductive in [15], which has S_{11} of near -8 dB at the f_r of 2.45 GHz. Overall, the S_{11} measurement in this study is acceptable since it is below than the -10 dB threshold.

It is found that the gain of the designed antenna array is 8.422 decibel isotropic (dBi) at the f_r of 2.437 GHz, which is a good antenna performance indicator. The designed antenna array also emits a significant directivity of 9.755 dBi with a high efficiency of 73.574 %. Radiation pattern is the directional dependence of the strength of radio waves from the antenna. Figure 12 clearly shows that the designed antenna array generates an isotropic radiation pattern. In other words, the designed antenna array emits equal electromagnetic radiation in all directions.

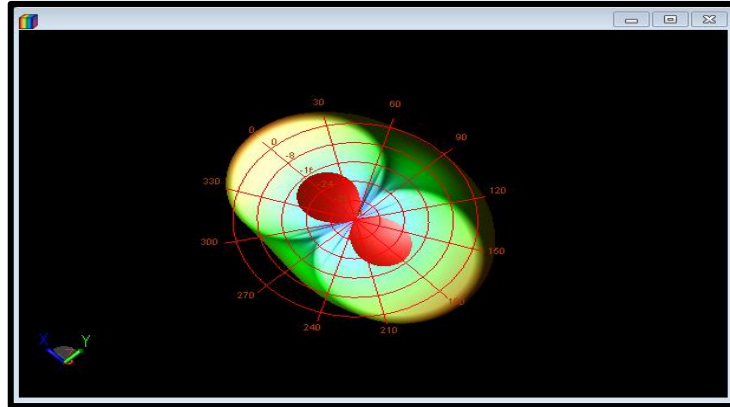


Figure 12. Microstrip patch antenna array 3d radiation pattern

The simulated performances of the bridge rectifier and the voltage doubler are compared in this study. The performances of both rectifier circuits are discussed in terms of the S_{11} characteristic of matching network and RF-DC Power Conversion Efficiency (PCE). Figure 13 shows that the designed bridge rectifier is matched at 2.45 GHz with S_{11} measurement of -20.512 dB and the normalized impedance equals to $1.128 - j0.155 \Omega$. Moreover, Figure 14 depicts that the designed voltage doubler is matched at 2.46 GHz with S_{11} parameter of -11.660 dB and the normalized impedance equals to $0.997 + j0.764 \Omega$. Both designed rectifier circuits have enough maximum power transferred from the antenna to the load.

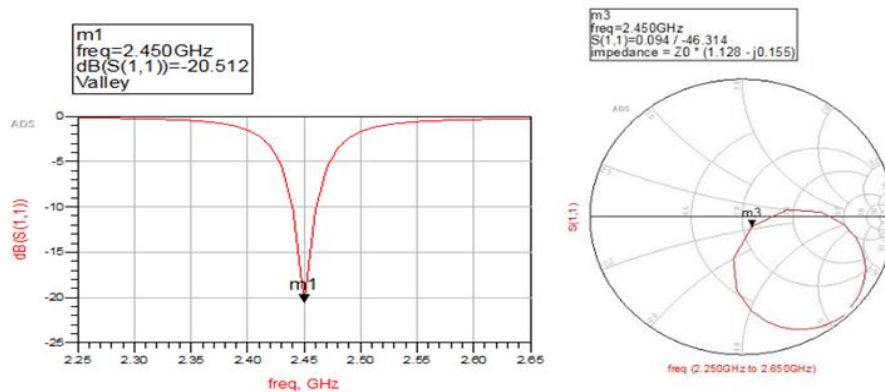


Figure 13. Reflection Coefficient (S_{11}) of Bridge Rectifier at 2.45 GHz

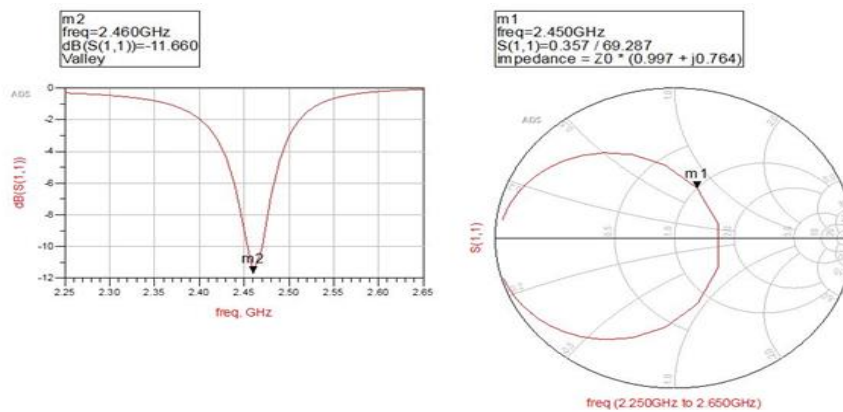


Figure 14. Reflection Coefficient (S_{11}) of Voltage Doubler at 2.45 GHz

The RF-DC PCE, η of the rectifier circuits is defined as follow:

$$\eta = \frac{DC\ Power}{RF\ Power} = \frac{P_{out}}{P_{in}} \tag{14}$$

Where,

$$P_{out} = \frac{Output\ DC\ Voltage}{Load\ Resistance} = \frac{V_{out}^2}{R_L} \tag{15}$$

Figure 15 shows the comparison of RF-DC PCE simulation between both rectifier circuits. It is found that the bridge rectifier design has the minimum of PCE of 3.48% with V_{out} of 132 mV and input power of 0 dBm or 1 mW whereas the voltage doubler has the maximum of PCE of 20.40% with V_{out} of 5.68 V and input power of 25 dBm or 316.23 mW. Furthermore, the bridge rectifier has the maximum of PCE of 50.20% with V_{out} of 5.01 V and input power of 20 dBm or 100 mW whereas the voltage doubler has the maximum of PCE of 53.56% with V_{out} of 2.91 V and input power of 15 dBm or 31.62 mW, respectively.

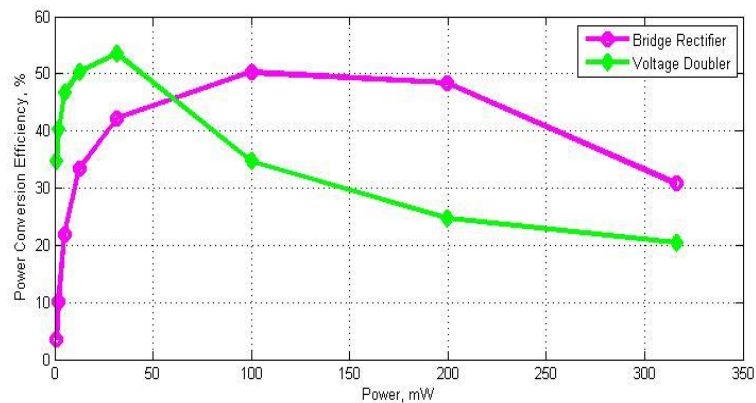


Figure 15. RF-DC PCE Comparison between Designed Rectifiers

4. CONCLUSION

In sum, jeans fabric can be as an alternative substrate whereas ShieldIt Super as an alternative conductive layer in the wearable microstrip patch antenna array design. This is based on the antenna performance adequate measurements. Both, the simulated and actual S_{11} measurements are acceptable, which are below than the required -10 dB threshold. Precisely, jeans relative permittivity, thickness, and ShieldIt Super conductivity are critical in affecting the dimension values of microstrip patch and inset-fed line. Moreover, the designed microstrip patch antenna array with two elements performs better than the counterpart with only one element using the same substrate and conductive material in terms of return loss.

Besides, both the bridge rectifier and voltage doubler design matched at the resonant frequency, f_r near to 2.45 GHz with simulated S_{11} parameters below -10 dB threshold. The simulated impedance matching magnitude for the bridge rectifier circuit is 56.93 Ω and the voltage doubler is 62.80 Ω . These are quite acceptable since near to the characteristic impedance, Z_0 of 50 Ω . The bridge rectifier generates significant simulated DC V_{out} ranges from 132 mV to 5.01 V with the corresponding PCE between 3.48% and 50.20% whereas for the voltage doubler, the DC V_{out} is from 417 mV to 2.91 V with the respective PCE between 34.78% and 53.56%.

In the future, it is recommended to use substrate that is water proof instead of jeans fabric that easily absorbs water, hence affect antenna performance. In addition, there will be a fabrication of rectifier circuits so that the 2.45 GHz Wireless Local Area Network (WLAN) or Wi-Fi signal can be harvested and converted to considerable DC voltage. Besides, it is suggested to apply the complete fabrication of wearable rectenna in a specific position in clothing and test it in a real environment where factors, such as weather condition, friction with other wearing fabric and scratch due to the surrounding object will be considered in the antenna performance analysis.



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REFERENCES

- [1] E. G. Lim, et al., "Compact Size of Textile Wearable Antenna" in Proc. of the Int. MultiConf. of Engr. and Comp. Sc. (IMECS), vol. 2, 2014.
- [2] C. Parmar & S. Joshi, "Wearable Textile Patch Antenna for On-Body Communications", in Proc. of Global Conf. on Comm. Tech. (GCCT), 2015.
- [3] S. R. Mohd Zaini & K. N. Abdul Rani, "Wearable Inset-Fed FR4 Microstrip Patch Antenna Design", in Proc. of Malaysian Technical Univ. Conf. on Engr. and Tech. (MUCET), vol. 318 (012050), pp. 1-9, March 2018.
- [4] M. I. Ahmed, et al., "Investigation and Comparison of 2.4 GHz Wearable Antennas on Three Textile Substrates and its Performance Characteristics", Open Journal of Antennas and Propagation, vol. 5, pp. 110-120, Sep 2017.
- [5] S. E. Adami, et al., "A Flexible 2.45-GHz Power Harvesting Wristband With Net System Output From -24.3 dBm of RF Power", IEEE Trans. on Microwave Theory and Tech., vol. 66, no. 1, pp. 380-395, 2018.
- [6] B. Naresh, et al., "Dual Band RF Energy Harvester for Wearable Electronic Technology", in Proc. of 3rd Int. Conf. on Advances in Electrical, Electronics, Info., Comm. and Bio-Informatics (AEEICB), pp. 274-277, 2017.
- [7] I. Adam, et al., "Double Band Microwave Rectifier for Energy Harvesting", Microwave and Optical Tech. Letters, vol. 58, no. 4, pp. 922-927, 2016.
- [8] S. E. Adami, et al., "A 2.45 GHz Rectenna Screen-Printed on Polycotton for On-Body RF Power Transfer and Harvesting", in Proc. of IEEE Wireless Power Transfer Conf. (WPTC), pp. 1-4, 2015.
- [9] A. Galoić, et al., "Wearable Energy Harvesting Using Wideband Textile Antennas", in Proc. of the 10th European Conf. on Antennas and Propag. (EuCAP), April 2016.
- [10] H. A. Rahim, et al., "On-body Textile Monopole Antenna Characterisation for Body-centric Wireless Communications", in Proc. of the Prog. in Electromagnetics Res. Symp. (PIERS), pp. 1377-1380, Aug. 2012.
- [11] M. S. Shakhirul, et al., "1.575 GHz Circular Polarization Wearable Antenna with Three Different Substrate Materials", in Proc. of the IEEE Asia-Pacific Conf. on Applied Elect. (APACE), Dec. 2014.
- [12] I. Gil. & R. Fernández-García, "Wearable GPS Patch Antenna on Jeans Fabric", in Proc. of Progress in Elect. Res. Symp. (PIERS), pp. 2019-2022, Aug. 2016.
- [13] S. D. Murali, et al., "Development of Wearable Antennas with Different Cotton Textiles", International Journal of Engineering Res. and App., vol. 4(7), pp. 8-14, July 2014.
- [14] E. N. F. S. Engku Embong, et al., "The Wearable Textile-Based Microstrip Patch Antenna Preliminary Design and Development", in Proc. of IEEE 3rd Int. Conf. on Engineering Technologies and Social Sciences (ICETSS), pp. 1-5, March 2018.
- [15] J. S. Chen, et al., "Wearable Textile Microstrip Patch Antenna for Multiple ISM Band Communications", in Proc. of the IEEE Antennas and Propag. Society Int. Symp. (APSURSI), July 2013.

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