Performance analysis at the off body environment in terms of impedance matching, return loss and VSWR for wearable antenna system on different materials

by Endah Setyaningsih

IOP Conf. Series: Materials Science and Engineering **508** (2019) 012075 doi:10.1088/1757-899X/508/1/012075

Performance analysis at the off body environment in terms of impedance matching, return loss and VSWR for wearable antenna system on different materials

Joni Fat[1]*, Syah Alam[2] and Indra Surjati[3]

[1]Department Electrical of Engineering, Faculty of Engineering Universitas Tarumanagara

[2]Syah Alam, Department Electrical of Engineering, Faculty of Industrial and Technology, Universitas Trisakti

[3]Indra Surjati, Graduate Programe of Electrical Engineering, Faculty of Industrial and Technology, Universitas Trisakti

*jonif@ft.untar.ac.id

Abstract. In the increasing popularity of Internet of Things (IoT), Body Area Network (BAN) becomes much more important than before. The applications are vast and vary. This means a wearable antenna will become a necessity. This paper proposes design for a wearable antenna, which is a rectangular microstrip patch antenna. The focus of this paper is to design the microstrip antenna with textile materials as the substrate such as panama, cotton and silk. For comparable reason, the FR-4 substrate which is a popular substrate for constructing microstrip patch antenna is used as a comparison. The parameters observed in this paper are the return loss, VSWR and input impedance of each materials. After performing the simulation process using AWR Microwave Office, we can conclude that the substrates which used textile fabrics are acceptable and meet the minimum criteria for Body Area Network at working frequency of 2.45 GHz. The result of return loss, VSWR and input impedance show acceptable compare to FR-4. This study is usefull for BAN application in order to achieve wearable microstrip antenna with compact dimension .

Introduction

With the popularity of Internet of Things (IoT), the urges for a wearable antenna are undeniable. By the year of 2020, some predict that there will be approximately 20 – 50 millions devices that could be categorized as IoT devices [1]. These devices are ranged from sensors, actuators, microcontrollers, tags, and etc. One of the charactistics of IoT is the usage of wireless network. The networks that we talk in IoT are from Body Area Network (BAN), Personal Area Network (PAN), Local Area Network (LAN), Wide Area Network (WAN), Metropolitan Area Network (MAN) and also the Internet. Especially for BAN and PAN, there are many areas of interest that need to be researched. In this paper, we focused also for BAN and PAN, but in antenna perspective.

We know, the popularity of Bluetooth and Wi-Fi techonologies are in the peak. But in this study, we focused on microwave frequency of 2450 MHz, hence Bluetooth and Wi-Fi are operated at the frequency of 2400 MHz. This is because 2450 MHz is the frequency for the Industrial, Scientific and Medical

(ISM) band [2]. We do not design antenna for an inside body implementation. We just design antenna that should intended to be wearable, but in this study, we do not make a study directly or indirectly on the body. We just study and compare the dielectric materials (substrate) that could be categorized as fabric textiles [3]. We used a famous Printed Circuit Board (PCB) material as a control, i.e. FR-4.

2. Materials and Method

2.1. Materials

The materials that we used in this study are as in Table 1. We used three materials that could be categorized as fabric textile [3, 4, 5], and then one material which is not a textile. We select these materials based on the specifications that are available for constructing microstrip antenna. In Table 1, we showed the material names, theirs dielectric constant (ε_r) values, its height, and also tan δ.

Table 1. Antenna Materials

Material	ε_r	Height (mm)	tan δ
FR-4	4.3	1.6	0.0265
Panama Textile	2.12	1.6	0.05
Cotton Fabric	1.6	1.524	0.04
Silk Fabric	1.75	1.524	0.012

2.2. Method

We used a simulation as the proved of our works. We used rectangular patch in this simulation. The dimension of the patch is calculates using the following equations [6]. Equation (1) is for computing the width of the patch. Equation (2) and (3) are for the length of the patch.

$$W = \frac{c}{2 \cdot f \cdot \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (1)$$

$$L_{eff} = \frac{c}{2 \cdot f \cdot \sqrt{\varepsilon_{reff}}} \quad (2)$$

$$L = L_{eff} - 2\Delta L \quad (3)$$

From these equations, in order to obtain the patch dimension, we need *f* for frequency and ε_r. As we stated earlier, we use the frequency of ISM band, i.e. 2.450 MHz, and for the ε_r, we obtain from Table 1. The dimensions of the patches are in Table 2. The patches shape of each material are shown in Figure 1 until Figure 4.

Table 2. Dimensions of The Patches

Material	W (mm)	L (mm)	w (mm)	X (mm)	Y (mm)
FR-4	40	29	3.1	50	50
Panama Textile	50	42	5.02	60	80
Cotton Fabric	97	99	5.3	120	150
Silk Fabric	77	91.6	5.3	120	150

After we shaped the patches with the dimensions that we have computed, we run the simulation in the range of frequency that included the ISM band. We used the range of frequency from 2 GHz to 3 GHz with the step of 0.5 GHz. We drew the graphs for return loss, VSWR and input impedance. Then, we verified the results.

IOP Conf. Series: Materials Science and Engineering **508** (2019) 012075 doi:10.1088/1757-899X/508/1/012075

3. Results and Discussion

3.1. Result and Discussion for Return Loss

The return loss graphs for each material are shown in Figure 5. We used color codes to differentiate each material. The overall results for return loss are acceptable because all values are under -9.54 dB [7]. The best return loss is obtained by using the cotton fabric substrate, i.e. -33.53 dB. FR-4 substrate which we used as control gave us the value of -22.53 dB. Sure enough, cotton and panama textile (-31.97 dB) are far more supperior than the control. The worst is silk fabric, but this value is more than enough to be acceptable.

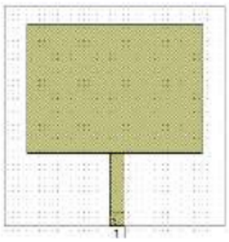

Figure 1. Microstrip Antenna Patch Shape for FR-4 material

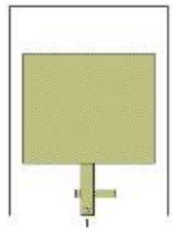

Figure 2. Microstrip Antenna Patch Shape for Panama Textile Material

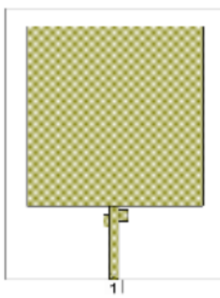

Figure 3. Microstrip Antenna Patch Shape for Cotton Fabric Material

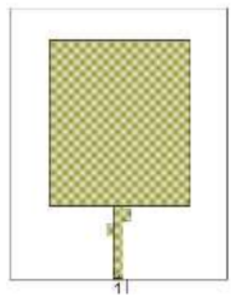

Figure 4. Microstrip Antenna Patch Shape for Silk Material

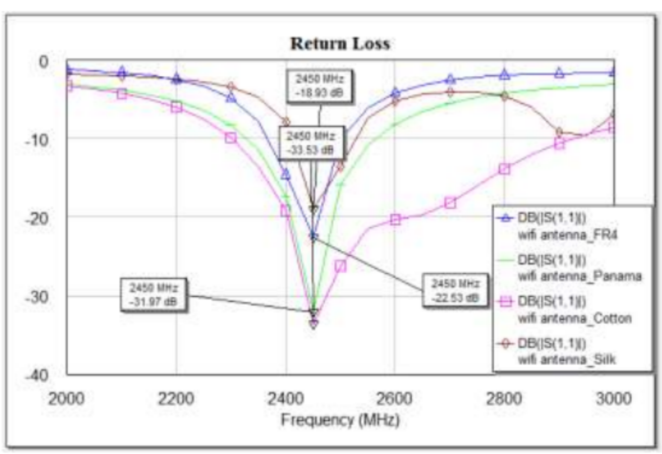

Figure 5. Return Loss

3.2. Result and Discussion for VSWR

VSWR is a ratio between the maximum value and the minimum value of the voltage standing wave in a transmission line. This value gives us a glance to what is happening in the transmission line. The ideal value of VSWR is 1, which is meant to be perfect match or no reflection in the transmission line. The accaptable value is under 2 [7]. Our testing result shew that the VSWR for each material were accaptable. Figure 6 shows the result. Cotton fabric gave the best VSWR which was 1.045. The control (FR-4) is 1.162. Panama textile gave us 1.053 and silk fabric is 1.257. We could see that order of these values are the same as return loss. The order from best to worst is cotton fabric, panama textile, FR-4 and silk fabric.

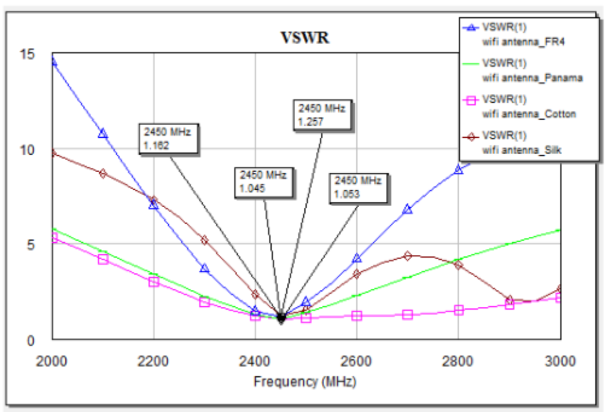

Figure 6. VSWR

3.3. Result and Discussion for Input Impedance

The purpose of this input impedance is to achieve perfect matching or no reflection in the end of load line. We knew that impedance of the transmission line is equal to 50 Ω [7]. So, the input impedance should equal to this value. In normal form, it should be Z_{in} = 1. It is hard to achive this value for the frequency that we would like to receive. So, we accept the approximate value. Figure 7 show the result of our testing.

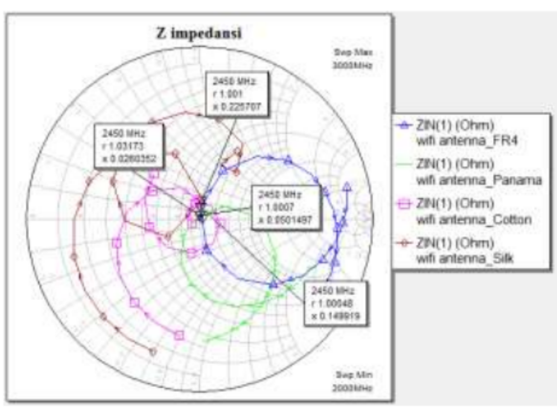

Figure 7. Input Impedance

We wrote down the values in complex form as in Table 3. From these values, we could conclude that the real part is almost equal to 1, and the imaginary part is almost equal to zero. The biggest real part is cotton fabric, i.e. 1.03173 and the imaginary part is silk fabric, i.e. 0.225707. We think that all the Z_{in} values in the test are still acceptable. We proved these by observing the electromagnetic field.

Table 3. Input impedance in complex normalized form

Material	Z_{in} (Ω)
FR-4	1.00048 + j0.149919
Panama Textile	1.0007 + j0.0501479
Cotton Fabric	1.03173 + j0.0260352
Silk Fabric	1.001 + j0.225707

4. Conclusion

From the testing that we have conducted and after analyzed the results, we could confident that using substrate which could be categorized as textiles are acceptable. There should be additional testings to find the optimum patch shape for each material, but this could be achieved as our results have proved. Our results also shew that some subtrates could give a better results that the control (FR-4), but this could be caused by the control was not optimize. We have no verification. By this study, we conclude that wearable antenna using textile materials as substrate are acceptable.s

5. References

[1] S. Smith, 2016, *Internet of Things connected devices to triple by 2021, reaching over 46 billion units*, in Juniper Research.

[2] J. Gemio, J. Parr´on, and J. Soler, 2010, *Human Body Effects on Implementable Anttenas for ISM Bands Applications: Models Comparison and Propagation Losses Study*, *Progress In Electromagnetics Research*, Vol. 110, 437–452.

[3] S. Dhupkariya, V. Kumar Singh, and A. Shukla, 2015, *A Review of Textile Materials for Wearable Antenna*, *Journal of Microwave Engineering & Technologies*, ISSN: 2349- 9001 (online), Vol. 1, Issue 3, pp. 7-14.

[4] S. Deya, et. al., *Design of Wearable Antenna System on Different Materials & Their Performance Analysis at the Off and On Body Environment in terms of Impedance Matching and Radiation Characteristics*, 2013, *American Academic & Scholarly Research Journal*, Vol. 5, No. 5, pp. 181-192.

[5] *Fabric Thickness and Weight*, 2018, https://propercloth.com/reference/fabric-thickness-weight/.

[6] S. Alam, I. G. N. Y. Wibisono, 2017, *Pengantar Antena dan Propagasi: Konsep Dasar dan Teori*, Jakarta: UTA'45 Jakarta Press, pp. 22-24.

[7] I. Surjati, 2010, *Antena Mikrostrip: Konsep dan Aplikasinya*, Jakarta: Universitas Trisakti.

Performance analysis at the off body environment in terms of impedance matching, return loss and VSWR for wearable antenna system on different materials

ORIGINALITY REPORT

16%	11%	14%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	repository.unpar.ac.id Internet Source	5%
2	Indra Surjati, Syah Alam, Lydia Sari, Yuli Kurnia Ningsih, Elfi Syukriati, Aida Safitri. "Circular Polarization Microstrip Antenna Array 1×2 For Microwave Radio Communication", 2019 IEEE International Conference on Communication, Networks and Satellite (Comnetsat), 2019 Publication	2%
3	www.uta45jakarta.ac.id Internet Source	1%
4	Amalia Nurul Balqis, Lianda Ramadhana, Rio Wirawan, Ika Nurlaili Isnainiyah. " - : An android application for online fish auction based on case study from Muara Angke, Indonesia ", IOP Conference Series: Materials Science and Engineering, 2019 Publication	1%

5	patents.justia.com Internet Source	1 %
6	Syah Alam, Anggy Pradiftha Junfithrana, Indra Surjati, Yuli Kurnia Ningsih, Lydia Sari, R. Deiny Mardian. "Design of Microstrip Antenna With Dual Feed Line For Improving Bandwidth and Axial Ratio", 2019 5th International Conference on Computing Engineering and Design (ICCED), 2019 Publication	1 %
7	"Handbook of Antenna Technologies", Springer Science and Business Media LLC, 2016 Publication	1 %
8	lppm.ub.ac.id Internet Source	1 %
9	Isidoro Ibanez Labiano, Akram Alomainy. "Fabric Antenna for Temperature Sensing over ISM Frequency Band", 2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting, 2019 Publication	1 %
10	Efri Sandi, Baso Maruddani, Nabillah Khairunisa. "Complementary Split Ring Resonator on the Ground Plane for Wearable Antenna", 2020 International Conference on	1 %

Radar, Antenna, Microwave, Electronics, and Telecommunications (ICRAMET), 2020
Publication

11	systemcontrols.co.in Internet Source	1 %
12	eprints.utm.my Internet Source	<1 %

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		