DEVELOPMENT OF FLEXIBLE WEARABLE ANTENNA FOR ISM BAND APPLICATION

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Development of The Star Patch Wearable antenna for ISM Band Application

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***Abstract*— This paper proposes a prototype of wearable antenna by using a star patch design. The research objective is mainly to observe some of the characteristic of the wearable antenna that is bending on the curvy structure. During the initial study, an intensive literature has been conducted to investigate the effects of the substrate material, and some of the design of wearable antenna. The designs and simulations in this study are done using the Computer Simulation Technology (CST) Microwave Studio software. Time domain solver in CST is used to simulate the designs of the wearable antenna. This antenna is using the polyimide film as the substrate with dielectric permittivity ($\varepsilon_r = 3.4$). The polyimide film has a better performance in terms of flexibility, low loss tangent, dielectric constant, and high stability for the wearable application. The antenna performance has been measured such as (s_{11}), impedance bandwidth, radiation pattern, and gain. This antenna provides a minimum resonant frequency at 2.45 GHz which is the (s_{11}) is -27.67 dB in the flat condition. The impedance bandwidth of the star patch antenna is relatively large, which is 610 MHz it could overcome the shifted resonant frequency caused by the bending effect. From the study, it is found that the star patch antenna offers the best performance in terms of return loss, bandwidth, radiation pattern, and gain. Star patch antenna is also less affected by the effects caused by bending the antenna. Comparisons between the simulated and measured results for proposed antenna will be discussed in this paper.**

Keywords*— Wearable Antenna, Star Patch design, ISM Band, WBAN

I. INTRODUCTION

Wireless multimedia systems are now paying more attention to the study of wireless body area network (WBAN). WBAN links various electronic devices in and on the human body [1]. The application of WBAN has been expanding in medical services, military defense, wearable computing, flexible electronic and so on. Several frequency bands have been assigned for WBAN systems, such as the Medical Implant Communication System (MICS: 400 MHz) band, the Industrial Scientific Medical (ISM: 2.45 GHz and 5.8 GHz) band, and the Ultra-wideband (UWB: 3-10 GHz), [2-6].

In the future, a person tends to carry a variety of devices and sensors, including medical sensors that can constantly communicate with each other and the outside world. It is very important to provide this functionality as quietly as possible. A key technology for achieving this goal is wearable electronics and antenna. Because nearly global availability, which is 2.45 GHz unlicensed ISM band is used for the development of wearable antennas. For user convenience, wearable antennas need to be compact and a low profile. This requires the integration possibilities for these antenna used in everyday clothes. Microstrip patch is candidates for each application wearable because it can be made conformal for integration in the clothes[7,8].

The development and utilization of wearable antennas have grown rapidly in recent years for application in the miniaturization of wireless communication devices. The main advantage of wearable antennas is that they are designed as elements of clothing able to transmit or receive wireless signals [8,9]. The wearable antenna system plays an important role in many fields, including tracking and navigation, mobile computing and public safety.

The wearable antenna used as a part of clothing depends on the body curve, so it can affect the performance of the wearable antenna in terms of the return loss, radiation pattern, and antenna gain. The resonant frequency and return loss of the antenna can be shifted or decreased when rolled on curved surfaces. Besides, the radiation pattern of the antenna also can be distortion and degradation when the antenna stretched, rolled, or twisted. So, the wearable antenna must be passed to the flexibility performance test in terms of resonant frequency, radiation pattern, gain antenna under various bent condition.

The purpose of this research discusses some of the challenges to measure analysis the wearable antennas under different bending conditions. Initially is to measure the flexibility performance of the proposed antenna such as return loss (s_11), radiation pattern, and gain in free space. Based on the statement, the high performance wearable antenna is accomplished by designing a good performance design that can cooperate with human a body.

II. ANTENNA GEOMETRY

The geometry of the proposed antenna similar in [10] as shown in Figure 1. The proposed antenna was fabricated on polyimide film substrate with the dielectric permittivity (ε_r= 3.4), loss tangent is (δ=0.002), and the thickness of the substrate is 0.8 mm. The Feeding technique of this antenna is using microstrip-line feed with a 50 Ω. The overall size of the proposed antenna is 75 x 50 mm. The rectangular slot on the ground plane are introduced to produced the omnidirectional radiation patterns of this antenna.

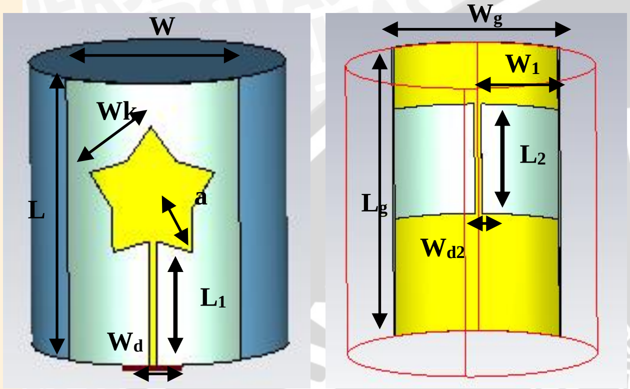


Figure 1. Geometry of the star patch antenna

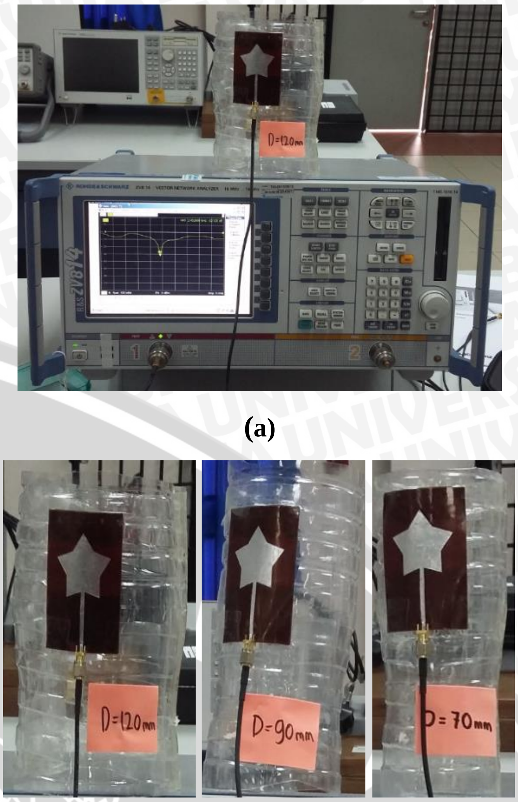
Fig. 1. The antenna design; X= the excitation port; with 1.6 mm FR-4 substrate (ε_r= 3.9) W= 50 mm; L= 75 mm; microstrip-line feed with the dimension of Ws= 3.372 mm; Wk= 21.8 mm; Rp= 18.5 mm; Ls= 34 mm; and ground plane with the dimension of Wg= 50 mm; Lg= 75 mm; Wg1= 15 mm; Wg2= 24 mm; Wg3= 2 mm; Wg4= 30 mm.

III. RESULT AND ANALYSIS

Next, simulated and measured result for the star patch design will be discussed under different bending condition. The data simulation was done by using on CST microwave studio. For the measurement setup was performed inside the anechoic chamber. Comparisons between the simulated and measured results for the star patch wearable antenna is discussed in this section.

A. S11 Result

The prototype of star patch antenna design is shown in Figure 2. The aluminum tape was used as a radiating element and connected by using SMA connector. To validate the simulated result of the antenna, the fabricated antenna was measured by using Rohde & Schwarz ZVB14 vector network analyzer.



(a)

(b) (c) (d)

Figure 2. (a) Return loss measurement setup the star patch antenna under various bending condition (b) 120 mm (c) 90 mm and (d) 70 mm

Figure 2 shows the return loss measurement setup for the star patch antenna rolled on a plastic cylinder under several diameter, which are 120 mm, 90 mm, and 70 mm.

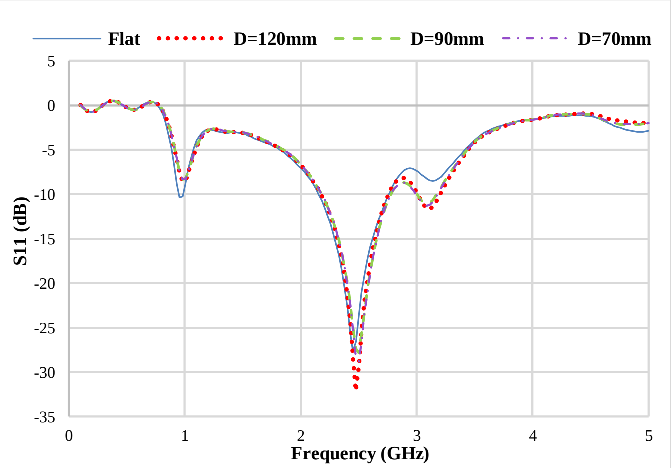


Figure 3. Simulated frequency response of star patch antenna under bending condition with different diameter

Figure 3 shows the simulated S11 result of the star patch antenna on curvy structure with a 120 mm, 90 mm, and 70 mm diameters. As can be seen in Figure 4.5, the resonant frequency 25 MHz shift to a higher resonant frequency is experienced when the antenna bent on curvy structure with 120 mm diameter. Meanwhile the resonant frequency shift 50 MHz to higher resonant when the antenna bent on 90 mm and 70 mm diameters. However, the bandwidth of the star patch antenna is relatively large, which could overcome the shift caused by the bending effect.

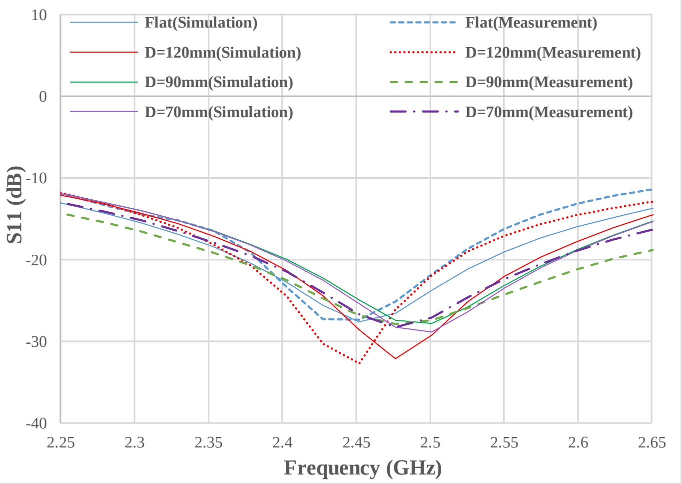
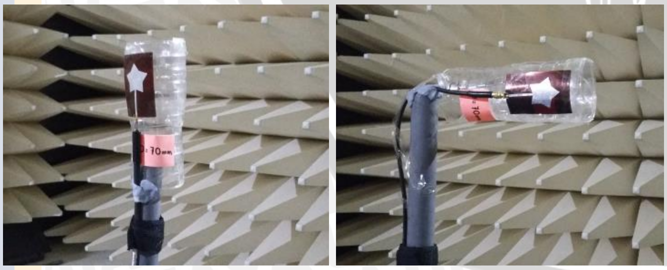


Figure 4. Simulated and measured frequency response of star patch antenna under bending condition with different diameter

Figure 4 shows the simulated and measured S11 result for the star patch antenna when bent on curvy structure with a 120 mm, 90 mm, and 70 mm diameters. As can be seen in Figure 4.10, the resonant frequency is not shift to a higher resonant frequency is experienced when the antenna bent on curvy structure with 120 mm diameter. Meanwhile the resonant frequency shift 58 MHz to higher resonant when the antenna bent on 90 mm. Then, resonant frequency shift 25 MHz to higher resonant when the antenna bent on 70 mm diameters. However, the bandwidth of the star patch antenna is relatively large, which could overcome the shift caused by the bending effect.

B. Radiation Pattern



(a) (b)

Figure 5. Radiation pattern measurement setup inside an anechoic chamber (a) E-plane (YZ cut) and (b) H-plane (XZ cut)

Far-field radiation patterns result of the star patch antenna have been measured in the anechoic chamber room. The comparison between simulated and measured of E-plane (YZ cut) and H-plane (XZ cut) far-field radiation pattern are shown in Table 2. The Antenna Under Test (AUT) was placed on an ETS-Lindgren 2090 positioner and aligned to a horn antenna with adjustable polarization.

Table 1. Simulated and measured far-field radiation pattern under different bending condition

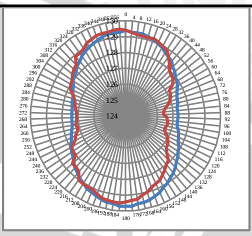
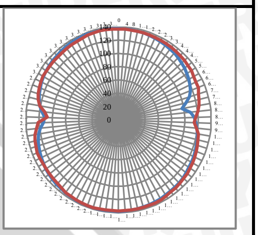
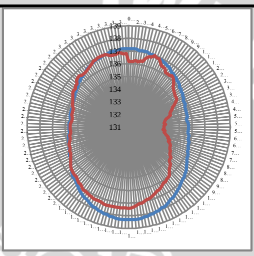
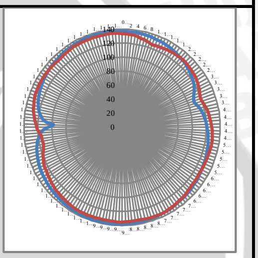
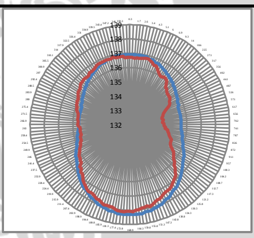
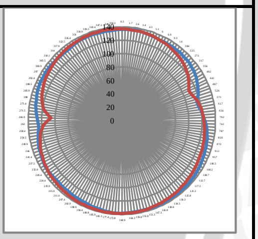
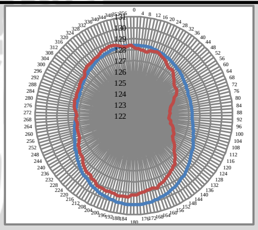
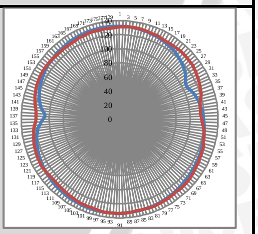
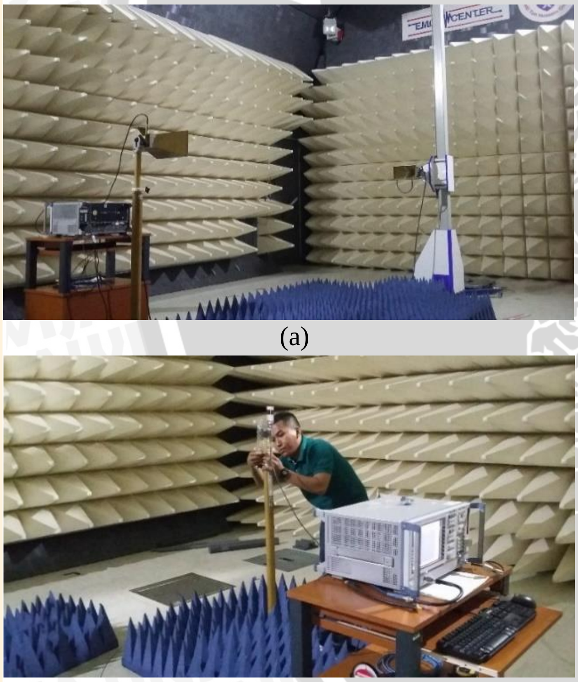
Condition	E-plane (YZ cut)	H-plane (XZ cut)
Flat		
D=120mm		
D=90mm		
D=70mm		
	Simulation Measurement	

Table 2 shows in all of the condition the antenna have an omnidirectional directivity at 2.45 GHz. The simulated result for E-Plane (Yz cut), in flat condition the antenna has a main lobe value which is 128.55 dBuV/m. Next, for bending condition the antenna have main lobe value which are 138.3 dBuV/m (120 mm), 138.3 dBuV/m (90 mm), and 130.1 dBuV/m (70 mm). Meanwhile, the main lobe value for measured result in flat condition is 129.7 dBuV/m. Then for bending condition the antenna have main lobe value which are 137.4 dBuV/m (120 mm), 138.05 dBuV/m (90 mm),and 129.3 dBuV/m (70 mm).

Furthermore, the simulated result for H-Plane (Xz Cut), in flat condition the antenna has a main lobe value which is 137.35 dBuV/m. Next, for bending condition the antenna have main lobe value which are 138.3 dBuV/m (120 mm), 138 dBuV/m (90 mm), and 133.09 dBuV/m (70 mm). Meanwhile, the main lobe value for measured result in flat condition is 135.1 dBuV/m. Then for bending condition the antenna have main lobe value which are 137.4 dBuV/m (120 mm), 138.3 dBuV/m (90 mm),and 131 dBuV/m (70 mm). Based on Table 2, radiation pattern of the antenna does not experience many changes when it bended on the curved surfaces. Moreover, the directivity of the star patch antenna is omnidirectional at 2.45 GHz.

C. *Antenna Gain*

The gain transformation method technique is employed in order to measure the antenna gain for the proposed antenna in the anechoic chamber room . Two horn antenna are set up as a gain reference for calibrate the vector network analyzer (VNA). Then change one of the horn antenna by the antenna under test (AUT). The comparison simulated and measured gain antenna result for star patch antenna will be discussed in this section.



(a)

(b)

Figure 6. Gain measurement setup (a) Calibration VNA using two horn antenna (b) Antenna Under Test (AUT)

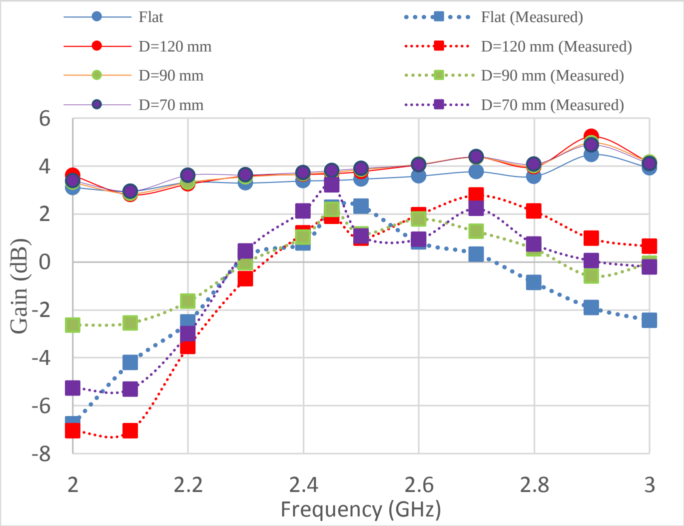


Figure 7. Simulated and measured gain of star patch antenna under bending condition with different diameter

Figure 7 shows simulated and measured result for star patch antenna gain under various bending condition. Based on Figure 7, in all of the condition the antenna have a gain above 3 dB at 2.45 GHz, which are 3.404 dB at flat condition, 3.686 dB at D=120 mm, 3.749 dB at D=90 mm, and 3.814 dB at D=70 mm. The star patch antenna that is bent in D=70 mm has higher gain than the other various bending condition. So, the antenna gain is increased when the proposed antenna getting rolled on a curved surface with a smaller diameter due to the surface current is increases when the antenna bent on smaller diameter.

IV. CONCLUSIONS

In summary, the wearable antenna that can operate 2.45 GHz is designed and fabricated. Uses of star patch design can offer good performance in terms of return loss, bandwidth, radiation pattern, and gain under various bending condition. Star patch antenna is also less affected by the effects caused by bending the antenna. From all of above analysis and simulation results, it can be observed, that the simulation method has better result than measurement result. Many factor causes the measurement result worth than simulation result as unperfect soldering that makes unmatching condition on port.

V. ACKNOWLEDGMENT

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