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Comparison of RFID Tag Structure for Wearable Applications System

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ABSTRACT

This paper proposed a comparison of Radio- Frequency Identification (RFID) tags for wearable applications. Three types of proposed RFID tag structures are designed which are square, hexagonal, and octagonal shapes to operate at frequencies 1.0 GHz to 12.0 GHz. The RFID tag structure consists of several meander line radiators. The structure of the meandered line radiator is attached to the cotton and jeans fabric. A monostatic radar system which consists of a Vector Network Analyzer and a horn antenna is configured to test the RFID tag in real life. The performances of RFID tags are evaluated in terms of the reflection coefficient (S_{11}) and their operating frequency. The results will be guidelines while designing RFID tag structures for wearable application systems in the future.

1. Introduction

Nowadays, the RFID system is broadly used in human applications from simple applications to advance tracking applications [1,2]. The RFID technology is based on the idea of using the incoming electromagnetic field to power up the necessary circuitry of an RFID transponder (or an RFID tag) and the communication is performed by modulating the backscattered signal. This idea allows the RFID tag to operate passively, based solely on the ambient electromagnetic energy provided by an RFID reader. Furthermore, Radio Frequency Identification (RFID) is a technology that has inherent benefits, such as successor to the technology of the bar code, wireless to communication, small size, light, inexpensive tags and brings many conveniences for people [3]. In addition, this technology can allow the integration of antenna with clothes.

The demand of consumer needs to use light, a thin and small item in their daily life as to bring it anywhere concurrently easier to attach to their body. Thus, the RFID tag is also required in small size, thin, and light, but mostly operates in single band frequency with a limit frequency. RFID can be used in a variety of applications, such as access management, tracking of persons and animals, toll collection and contactless payment, airport baggage tracking logistics, tracking, and billing processes, and others [4-16].

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Based on the previous research in Abdullah *et al.,* [17] and Abdullah *et al.,* [18], the RFID tag structure has been designed in the shape of square and hexagonal to operate at frequencies 1.0GHz to 12GHz. Another RFID tag structure is also designed which is an octagonal shape. Therefore, the comparisons of the RFID tag structure are analyzed in this article. The RFID tags have been designed in a small size (5cm to 6cm). The structure of the RFID tag is attached to cotton or jeans fabric. The RFID tag performances are evaluated in terms of operating frequency and reflection coefficients.

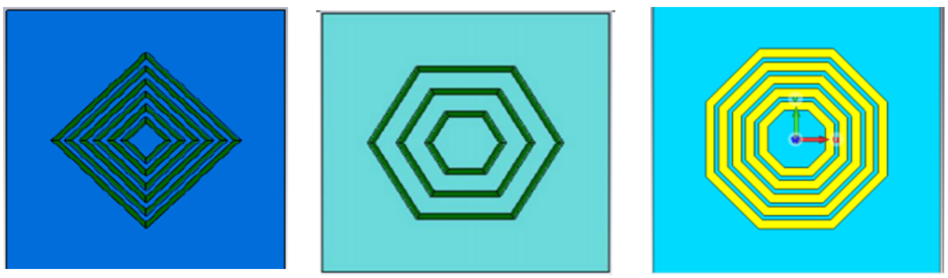
2. Comparisons of RFID Tag Structure

The RFID tag comprises a single metallic layer and a single substrate layer. A copper with 0.036 mm thickness is used as a metallic layer and it is printed on surfaces of the dielectric substrate. The dielectric constant is designed to operate at 2.40 GHz in a free-space environment. Generally, the size of the tag is 60 mm × 60 mm × 1.6 mm. The radiating element of the tag consists of a dimension curve with unique identification. For this project, the RFID tag is designed and attached to cotton or jeans fabric. Table 1 shows the material and parameter value for both fabrics.

Table 1
RFID Tags Configuration Parameters

Material type	Parameter	Value
Copper	Conductivity	5.96 x 10
Cotton	Dielectric constant	1.6
Jeans	Loss tangent	0.04

Figure 1(a) represents the RFID tag square shape structure with 6 slots nested loops that give the unique ID of 111111. The RFID tag is designed with 1 slot up to 6 slots nested loops in its substrate. Each slot has a width of 2 mm. The removed nested slot represents their unique ID as 0. Figure 1(b) shows the RFID tag of the hexagon shape with the unique ID of 101010 while Figure 1(c) shows the RFID tag of the octagon shape with the unique ID of 111110. The outer slot is considered the biggest slot, whilst the near origin point of the shaped patch becomes smaller.



(a) (b) (c)

Fig. 1. Comparison of RFID tag structure: (a) Square shape (b) Hexagonal shape (c) Octagonal shape

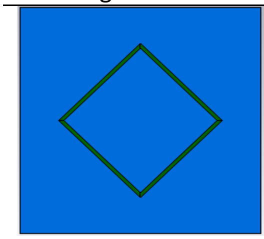
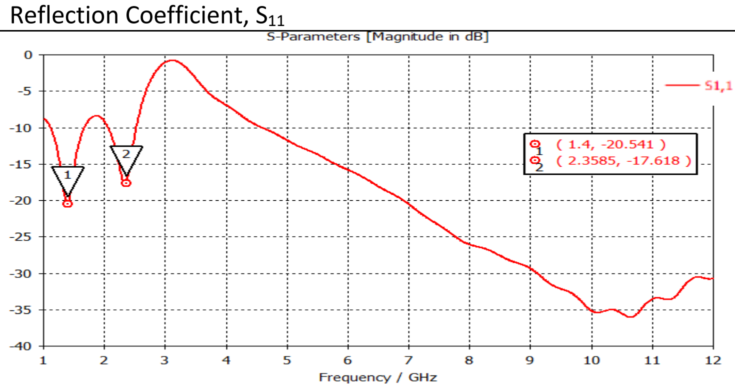
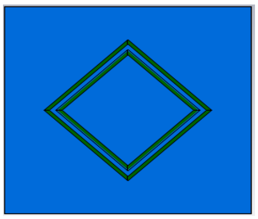
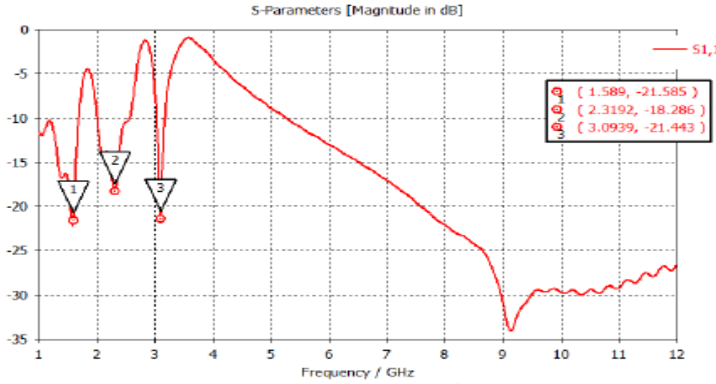
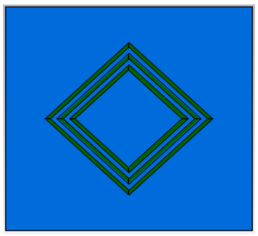
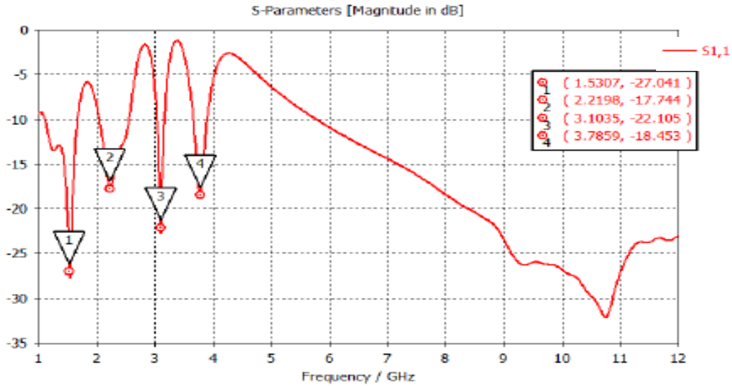
3. Comparisons of RFID Tag Performances

In this project, the monostatic radar system is used to detect and read the unique identification of the RFID tag. Each RFID tag has its own unique identification or spectral signature. Due to the use of the monostatic radar system, the unique identification or spectral signature of the RFID tag can be represented by the reflection coefficient (S_{11}) in CST Microwave Studio. The RFID tag uses a communication method called backscatter. The RFID tag will reflect the signal of the reader backward and modulate the signal to transmit data. The parameter of reflection coefficient (S_{11}) is used in CST Microwave Studio to represent the spectral signature of each proposed tag.

3.1 RFID Tag Structure of Square Shape

The RFID tag for wearable application systems is analysed based on the operating frequency and reflection coefficient. The unique identification (ID) or spectral signature of the RFID tag is represented by the reflection coefficient, S_{11} as the use of a monostatic radar system. The RFID tag uses a communication technique called backscatter. For this technique, the signal of the reader backward will be reflected and then modulate the signal to transmit data. The spectral signature of the RFID tag is represented by a parameter of S_{11}. Table 2 shows the RFID tag structure of a square shape with three different slot resonators nested attached to the jean's fabric. The ID of the RFID tag is generated by the presence of the slot resonator.

Table 2
The RFID tag structure of square shape with three different numbers of slot resonators nested

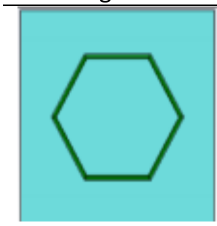
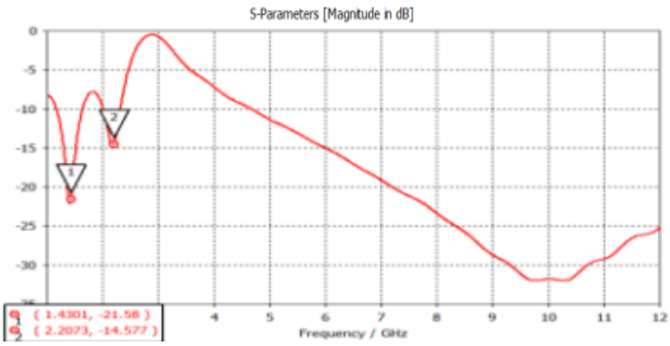
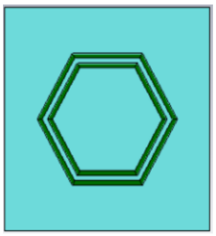
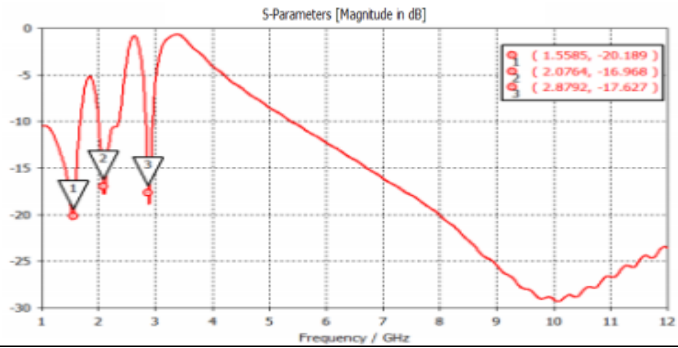
RFID Tag Structure	Reflection Coefficient, S_{11}
 (a) ID: 100	
 (b) ID: 110	
 (c) ID: 111	

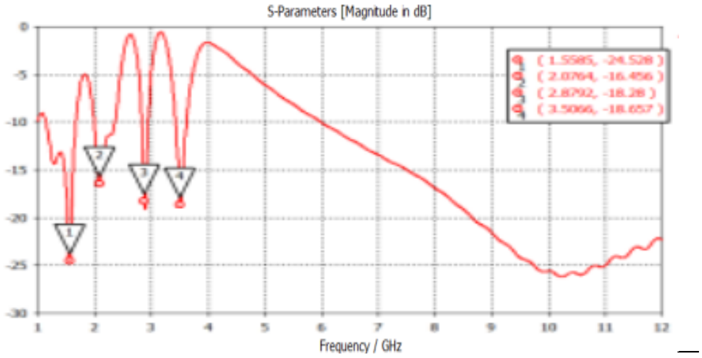
As analyzed in Table 2, each different number of slot resonator has its own unique spectral signature as represented by S_{11}. The presents of slots will be represented as bit '1', while the removal or not the presence of the slot resonator is stated as a bit '0'. The most outer slot resonator is considered the first slot resonator which can be operated at the lowest frequency. Meanwhile, the inner slot resonator is introduced as the last slot resonator that operates at the highest frequency. The ID for one, two, and three slots presented is known as 100, 110, and 111. Based on the results, the ID of the RFID tag is dependent on how many slot resonators are implemented. For the ID of 100, the operating frequency is 1.40 GHz and 2.35 GHz. For the ID of 110, the operating frequency is 1.6 GHz, 2.30 GHz, and 3.10 GHz. As mentioned previously, the operating frequency also depends on the number of lot resonators on the RFID tag structure.

3.2 RFID Tag Structure of Hexagonal Shape

Table 3 illustrates a hexagon design of an RFID tag with the different number of slot resonators nested in it and their S-parameter graph. Like before, the RFID tag performance is evaluated using the reflection coefficient, S_{11}. Based on the analysis of the reflection coefficient, S_{11}, the spectral signature of the RFID tag is represented by its unique identification.

Table 3
The RFID tag structure of hexagonal shape with three different numbers of slot resonators nested

<table>
<tr><th>RFID Tag Structure</th><th>Reflection Coefficient, S_{11}</th></tr>
<tr><td>
(a) ID: 100</td><td>
</td></tr>
<tr><td>
(b) ID: 110</td><td>
</td></tr>
</table>

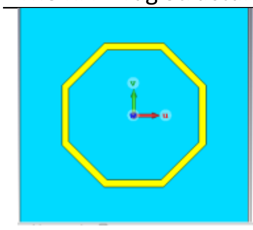
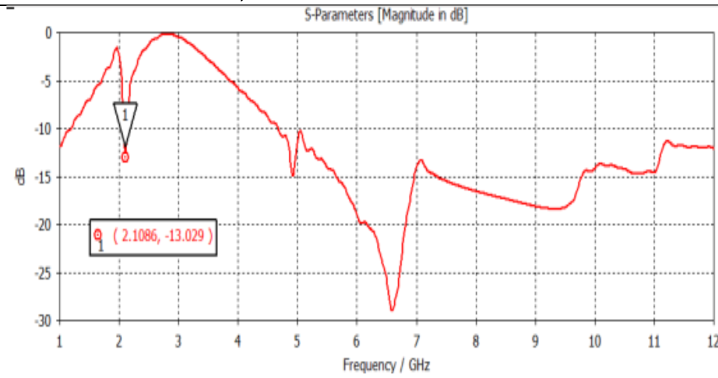
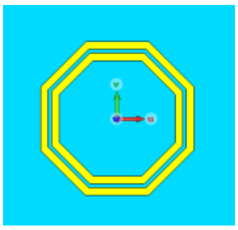
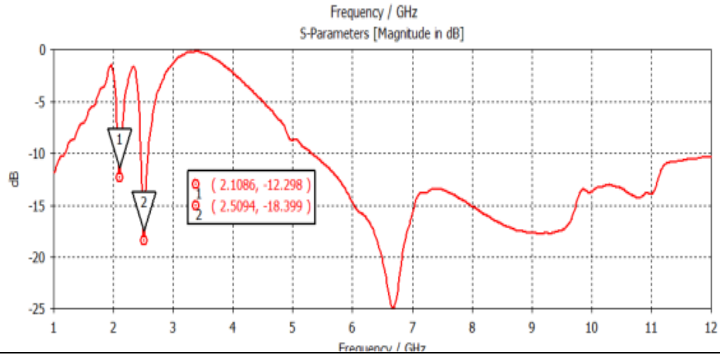
 (c) ID: 111	

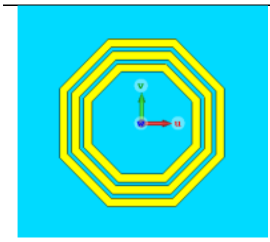
According to the results, the RFID tag is tuned at operating frequencies 1.43 GHz and 2.20 GHz as the one slot resonator is added and the unique identification (ID) namely 100. While the 2nd resonator is applied, the tag is tuned at operating frequencies 1.55 GHz, 2.07 GHz, and 2.87 GHz. The unique identification (ID) namely as 110. The 3rd RFID tag has 3 slot resonators within it and the tag is operated at 1.55 GHz, 2.07 GHz, and 2.87 GHz. Based on the analysis, each addition of slot resonators is generating another operating frequency. Like the previous simulation, the existing slot is representing ‘1’ for a unique identification number. The elimination of the slot is representing ‘0’ for a unique identification number.

3.3 RFID Tag Structure of Octagonal Shape

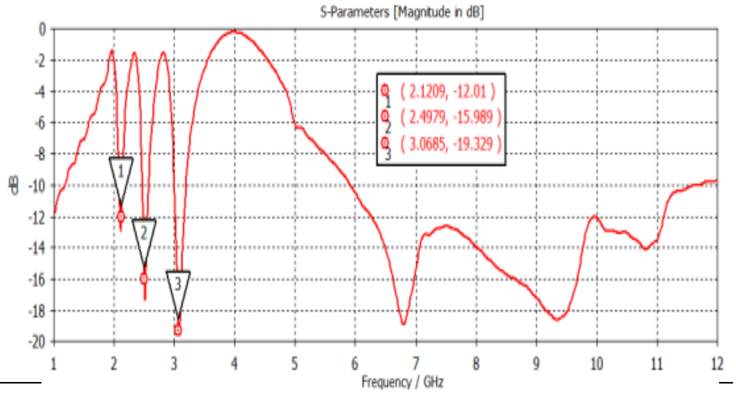
The results of the reflection coefficient of the RFID tag with an octagonal shape are shown in Table 4. The tag is attached to the cotton fabric as the substrate material. A different ID is generated for a different number of added resonator slots.

Table 4
The RFID tag structure of octagonal shape with three different slot resonators nested

The RFID Tag Structure	Reflection Coefficient, S_{11}
 (a) ID: 100	
 (b) ID: 110	



(c) ID: 111



The presence of one slot radiator with an octagonal shape tuned the operating frequency at 2.07 GHz along a reflection coefficient of -15.236 dB. The unique identification of the tag structure is named 100. While adding another slot resonator, the operating frequency is tuned to two frequencies which are 2.08 GHz and 2.47 GHz along with reflection coefficients of -14.043 dB and -21.089 dB. The unique identification of the tag structure is named 110. As the 3-slot resonator is added, the operating frequency is tuned to three frequencies which are 2.08 GHz, 2.47 GHz, and 3.04 GHz along with reflection coefficients of -14.698 dB, -21.089 dB, and -22.697 dB. The unique identification of the tag structure is named 111.

4. Analysis Results of Three Shapes of RFID Tag Structure

There are three patterns shape that has been designed for RFID tag structure. The result of the reflection coefficient for different shape designs is below -10 dB. The most outer slot resonator is considered the first slot resonator which can be operated at the lowest frequency. Meanwhile, the inner slot resonator is introduced as the last slot resonator that operates at the highest frequency. The ID for one, two, and three slots presented is known as 100, 110, and 111. Based on the analysis, all the tag structure provides almost similar performances in terms of operating frequency and reflection coefficient. As the slot resonant is added to the tag structure, the new operating frequency is generated. The shape and substrates do not influence the RFID tag performance.

5. Conclusion

The RFID tag for wearable application systems is successfully designed at the frequency of 1.00 GHz - 12.00 GHz for three shape structures which are pentagonal, hexagonal, and octagonal. Based on the simulated results, the different number of slot resonators of RFID tags is having different spectral signatures within the desired frequency which can be used as its unique identification. However, all the tag structure provides almost similar performances in terms of operating frequency and reflection coefficient although there have different shape structure and substrates. The results of the simulation can be a guideline while designing RFID tag structures in the future.

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