A RFID Tag Antenna for Wearable Application System in Microwave Frequency Band

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Abstract. A RFID tag antenna for wearable application system in microwave frequency band is proposed and presented. The proposed RFID tag antenna is operated in the microwave frequency band of 1 to 12 GHz. Several numbers of the slot resonator are introduced that attached on jeans fabric as substrate material. The presence of the slot resonator also will be used to generate the unique identification or spectral signature of the RFID tag antenna. In real life, the monostatic radar system, which consists of the Vector Network Analyzer and a horn antenna is configured to test the RFID tag antenna. The performances of the proposed RFID tag antenna are evaluated based on their reflection coefficient, operating frequency, and surface current. The obtained results give a good agreement between the measurements and simulation.

Keyword: microwave frequency, RFID, tag antenna, wearable application system

1. Introduction

Nowadays, the radio frequency identification (RFID) systems are widely used in various application from the elementary application to the prior tracking application [1-7]. Generally, there are two main types of RFID tags, which is passive and active RFID. In passive RFID, there are not requires batteries and the internal power source, which it is usually used to file tracking, race timing, supply chain and smart label. Meanwhile, the active RFID tags broadcast their own signal to transmit the information stored on their microchips. Usually, the RFID tag can be affixed to an object and used to track and manage inventory, assets, people, and others. In addition, RFID overture advantages over manual systems or use of bar codes [9-15]. The tag can be read even it is covered by the object or invisible. Unlike barcodes, the RFID can be used in a variety of application, and able be read hundreds at a time. However, the demands of the consumer which needs to use light, thin and small item in their daily life as to bring it anywhere concurrently easier to attached at their body. Thus, the RFID tag antenna is also required in small size, thin and light, but mostly operates in single band frequency with a limit frequency.

Therefore, the RFID tag antenna for wearable application is introduced in this article. The antenna has been designed as a small size, which is 5 to 6 cm with low power consumption. Furthermore, the RFID tag antenna for wearable identification is to have it unique identification. Thus, each of the RFID tag antenna will always have the difference unique identification. In this article, the RFID tag antenna for the wearable application is operated in the microwave frequency range of 1 to 12 GHz. The proposed RFID tag antenna represents by a microstrip based device that contains two planes only.
The cooper is used as material for the patch, while the substrate plane is jeans fabric. Jeans fabric is chosen due to its strength and ruggedness [6], their chemical resistance, easy to retrain shape, and have a low moisture absorption rate [7]-[8]. The antenna performances are evaluated in-terms of their operating frequency, reflection coefficient and surface current. The design of the RFID tag antenna for the wearable application is executed using CST Microwave Studio Software. Meanwhile, the validation of the RFID tag antenna is performed by using the Vector Network Analyzer (VNA) to analyze the communication link. Good agreement between the simulation and measurement have been obtained.

2. RFID Tag Antenna Configuration For Wearable Application System

The proposed RFID tag antenna configuration for wearable application systems is design via using CST Microwave Studio Software that tested by using material of jeans fabric. The RFID tag antenna is operated in the microwave frequency range from 1 GHz to 12 GHz. The RFID tag antenna is developed with the planar antenna, which evaluated in-terms of operating frequency, gain and efficiency. Generally, the RFID tag is a microstrip based device that consists of two layers which is known as patch and substrates layer. In this article, the jeans fabric is used as substrate material, while the conductive copper tape is represented as patch plane material. The patch and ground plane are a critical part in the microstrip based component as the best performance obtained of the components was depends on its characteristics. The conductive cooper as in Fig. 1 is chosen as material for patch because it can absorb the radio and other electromagnetic wave.

![Conductive copper tape as a shaped patch](image)

Fig. 1. Conductive copper tape as a shaped patch

The details of the parameter configurations of RFID tag antenna are stated in Table 1 and their configurations is illustrated in Fig 2.

| Type               | Parameter          | Value           |
|--------------------|--------------------|-----------------|
| Copper (Patch)     | Dimension          | 60mm x 60mm     |
|                    | Conductivity       | 5.96e+007 [S/m] |
|                    | Thickness          | 0.036 mm        |
| Jeans (Substrate)  | Dimension          | 39.51mm x 39.51mm |
| [7]-[8]            | Dielectric constants| 1.7             |
|                    | Loss tangent       | 0.025           |
| Slots (Nested loops)| Width             | 2 mm            |
Fig. 2. RFID tag antenna with unique ID of (a) 111111 and (b) 101010

Fig. 2 (a) represents the RFID tag antenna configuration with 6 slots nested loops that gives the unique ID of 111111. Meanwhile, Fig. 2 (b) shows the RFID tag antenna configuration when the slot nested at 2, 4 and 6 layers is removed. The removed nested slot represents their unique ID as 0. The outer slot is considered as the biggest slot, whilst the near to the origin point of the shaped patch is to become smaller. The implementation of the RFID tag design from the simulation into the actual configuration on the jeans fabric is shown in Fig. 3 below.

Fig. 3. Proposed RFID tag antenna on the jeans fabric

In this article, monostatic radar system is used to detect and read the unique identification of the RFID tag antenna. The performances of the proposed RFID tag antenna on the jeans fabric as for a wearable application system is presented in the next following section.

3. Results and Discussions
As mentioned before, the performances of the proposed RFID tag antenna for wearable application systems are observed in-terms of reflection coefficients, operating frequency range and surface current. Due to the use of monostatic radar system, the unique identification (ID) or spectral signature of the RFID tag antenna is represented by reflection coefficient, S_{11}. The RFID tag antenna use a communication method which called as backscatter. The signal of the reader backwards will be reflected and then modulate the signal to transmit data. The parameter of S_{11} represents the spectral signature of the proposed RFID tag antenna. Fig. 4 shows the various design of RFID tag antenna with different number of slot resonators nested. The presence of the slot resonator will generate the ID for the proposed RFID tag antenna.
(a) One slot resonator

(b) Two slots resonator

(c) Three slots resonator

(d) Four slots resonator

(e) Five slots resonator
The S\textsubscript{11} response of the proposed RFID tag antenna on the jeans fabric with various number of the slot resonator was illustrated in Fig. 4. The S\textsubscript{11} response for each different number of slot resonator have its own unique spectral signature. The dip in the spectrum of the S\textsubscript{11} response is depends on toward the slot resonators which nested in the circular patch of the RFID tag antenna. The dip of slots will be represented as bit ‘1’, while the remove or not presence of the slot resonator is stated as bit ‘0’. In addition, the most outer slot resonator is considered as the first slot resonator which can be produced the dip with the lowest frequency. Meanwhile, the inner slot resonator is introduced the last slot resonator that produced the dip with the highest frequency of the S\textsubscript{11} response.

Based on the obtained results in Fig. 4, the number of slot resonator added represented their own unique identification (D). The ID for Fig. 4 (a) to Fig. 4 (f) is namely as 100000, 110000, 111000, 111100, 111110, and 111111, respectively. Meanwhile, the operating frequency of the proposed RFID tag antenna is operated depends on how many slots resonator is implemented on the jeans fabric. Furthermore, the ID of the proposed RFID tag antenna also will be generated based on the presence or removed of the slot resonator on the jeans fabric as the substrate material. When some slot resonators is removed as in Fig. 5. The dip of slot resonator that have been removed is noted as bit ‘0’.

![Diagram of jeans fabric with slot resonators](image1.png)

Fig. 4. The S\textsubscript{11} response of the proposed RFID tag antenna on the jeans fabric with various number of the slot resonator

![Diagram of jeans fabric with slot resonators](image2.png)

Fig. 5. The S\textsubscript{11} response of the proposed RFID tag antenna on the jeans fabric when removed some number of the slot resonator
The proposed RFID tag antenna ID in Fig. 5 (a) and (b) is known as 101010 and 101101, respectively. As mentioned previously, the operating frequency also depends on the number of the slot resonator on the RFID tag antenna. Besides that, the surface current also investigated for the proposed RFID tag antenna on the jeans fabric with ID ‘101010’. The relationship between the operating frequency and surface currents for this ID is illustrated in the following Fig. 6.

As seen in Fig 6, the surface current of the proposed RFID tag antenna with ID ‘101010’ produced four dips in the $S_{11}$ spectrum as there is only three slot resonators nested. The current for each nested slot resonator which produce dips at certain frequency in the $S_{11}$ except for second, fourth and sixth slot resonators. The second, fourth and sixth slot resonators have been removed from the circular patch of the proposed RFID tag antenna. As well known, the operating frequency is dependent towards the number of the slot resonator, where it is relatively includes the $S_{11}$ response. Thus, the obtained results shown the relationship between the current surface and operating frequency. Consequently, the presence of the surface current in Fig. 6 for each slot resonators also indicates the dip at the certain frequency is produced as similar with the $S_{11}$ response.

Last but not least, the comparison between simulation and measurement of the $S_{11}$ response for the proposed RFID tag antenna with ID ‘101010’ on the jeans fabric is investigated. The obtained results are illustrated in Fig. 7.
The obtained results in Fig. 7 shows that the measurement results are slightly different in terms of their operating frequency, but the pattern of the $S_{11}$ response is still considered similar and acceptable. The $S_{11}$ responses for both have achieved a good performance, where its below than $-10$ dB. The operating frequency for the measurement is shifted from the simulation occurred due to the inaccuracy fabrication process. Even the changed dimension after fabrication is quite minor happened, the results will greatly be affected as it dependent in the dimension of the proposed RFID tag antenna. For the measurement process, the signal transmitted from the broadband horn antenna to the RFID tag antenna will occurs losses due to its distance and surroundings during the measured process.

4. Conclusions

As a conclusion, the proposed RFID tag antenna for wearable application systems operated in the microwave frequency band is successfully investigated. The proposed RFID tag antenna is affected by the number of the slot resonators presence or removed. The slot resonator is used to generate the unique identification (ID) of the proposed RFID tag antenna. The good agreement between the measurement and simulation are achieved, where their pattern of the $S_{11}$ response still similar and acceptable even their operating frequency is shifted. There is still hope for improvement by certain parameters of the antenna to have a better performance for wearable application system in microwave frequency band.

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