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The Embroidered Wearable Antenna for UWB Application

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ABSTRACT

This paper discusses the design of a wearable textile antenna for Ultra Wide Band (UWB) application. This embroidered antenna addresses the issues of miniature size, wide bandwidth and low power consumption. A textile cotton has been chosen as a substrate and silver nylon plated yarn as a conductive element embroidered on cotton substrate. Simulated and measured results show that the proposed antenna design meets the requirements of wide working bandwidth with compact size and flexible material. The performances in terms of reflection coefficient, impedance bandwidth, current distribution as well as gain and antenna efficiency are compared between simulations and measurements and good agreement was observed.

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INTRODUCTION

The development of wearable textile antenna becomes popular due to wide application of personal communication, wireless sensor and medical application. Other advantages that textiles antenna offer are, washable, flexibility, light weight, low cost and reliability. Generally, there are two manufacturing techniques to produce wearable textile antenna (Tomasz Maleszka, Pawel Kabacik, 2010) (i) Using conductive fabric fixed on the non conductive textile fabric and (ii) Using conductive textile yarns to weave, knit or embroider the conductive pattern of the antenna on the textile fabric.

The designing wearable textile antenna is quite challenging due to the effect of lossy environment such as humidity and temperature. Dimension wise, the selection of a proper textile in terms of dielectric permittivity, conductivity and loss tangent have to be determined (Van Langenhove, L., 2007; Yahya Rahmat –Samii, 2010).

The performance of the embroidered UWB textile antenna is studied at a frequency range between 3.1GHz to 10.6GHz. The embroidery technique is being preferred due to its robustness and esthetic value. Our study focuses on the performance effectiveness cause by the T-slot. The antenna embroidered circular antenna with and without T-slots performance is verified by comparing measurement and simulation result.

MATERIALS AND METHOD

Instead of using rigid circuit boards, cotton fabric is used as substrate, conductive fabric “Nora dell” as a ground plane and silver plated nylon thread as patch antenna. The properties of selected conductive fabrics may optimize the characteristics of the designed textile antenna in a specific application. Some of the electro-textiles properties they are flexible for deformation when worn, low electrical resistance to minimize losses, lightweight and comfortable. Therefore, the “Nora dell” has been selected. There are three Nora dell elements which are nickel, copper and nylon silver. Nora dell proposed a highly protective from galvanic corrosion and extremely flexible to the harsh environment of 90oC temperature (Yahya Rahmat –Samii, 2010).

Regarding fabrication techniques for textile antenna, a conductive thread need to be used in the embroidery techniques. Silver platted nylon thread is chosen as conducting materials that provide high quality conducting thread. According to the manufacturer specifications, this conducting material provides superior strength, ability to resist the normal conditions of use such as multiple deformations for wearable applications. In fact, the conducting thread can be washed with the ability to resist temperature up to 150°C (http://itp.nyu.edu/~kh928/sensorreport/ShieldexNoraDell.pdf). In embroidery technique, thread is sewn on the

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substrate will be penetrated at the back of the substrate. Hence, another layer of cotton will be inserted as to separate between the conductive thread and Nora dell as ground plane which means there are two layers of cotton fabric. Table 1 depicted the material used and their dimensions.

Table 1: Detailed of material used.

Antenna Components	Material	Dimension (mm)
Circular patch antenna	Silver plated nylon thread embroidered throughout the pattern on a cotton material	Radius =15
Substrate	Cotton	Thickness, h = 0.5
Ground Plane	Conductive fabric –"Nora dell"	Thickness, h = 0.13
Microstrip feed line	Silver plated nylon thread	30 X 2

A circular shape is mostly suited to UWB antenna which provides several advantages such as omni-directional, low transmit power and large channel capacity that suited the specification of UWB characteristic (Osman, M.A.R., 2011; Shih-HsuhHsu, Kai Chang, 2006). In this paper, two prototypes are simulated and their performances are compared.

A CST simulation tool has been used in designing the UWB antennas, however some modification has been made to suit the requirements. Initially a circular shape patch antenna was designed using cotton as a substrate with dielectric constant εr of 1.6. The resonance frequency, fr is 6.85GHz. The radius is calculated by using equation (1) while the patch antenna dimensions are calculated using basic equations for microstrip patch antenna (Shobanasree. R., S. Radha, 2012). Table 2 shows the summarized dimension for patch antenna and Fig. 1 shows the geometry of a modified design antenna for first and second designs respectively .

$$a = \frac{87.94}{fr(\sqrt{\varepsilon_r})} \quad (1)$$

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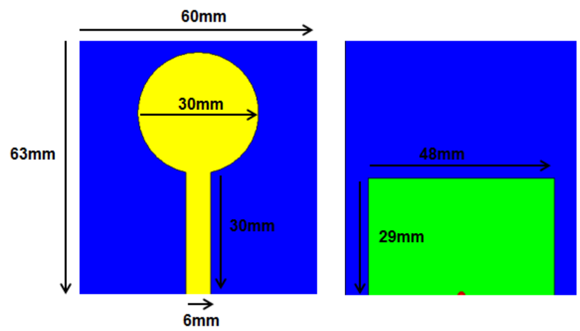
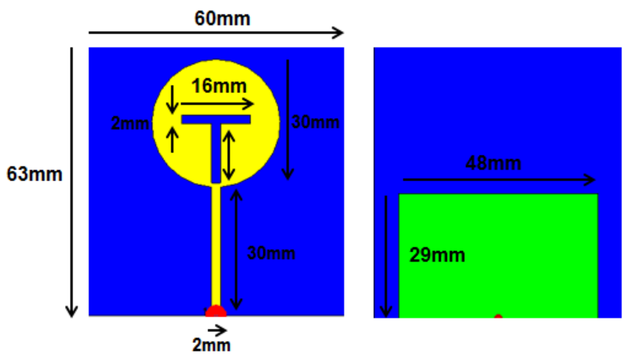
Table 2: Dimension of Modified Patch Antenna.

Parameter	Value
Patch width, *W*	60 mm
Effective dielectric constant, ε_{eff}	1.5025
Patch length extension, ΔL	0.3 mm
Patch length , *L*	63 mm



(a) The left sight is a front view while at the right sight is a back view of the antenna.



(b) The left sight is a front view while at the right sight is a back view of the antenna

Fig. 1: Optimum antenna dimension. (a) 1st design (b) 2nd design.

RESULTS AND DISCUSSIONS

All designs and simulations of both antennas are simulated by using CST The performance of the antenna is evaluated based on the reflection coefficient, gain, radiation pattern and the impedance bandwidth.

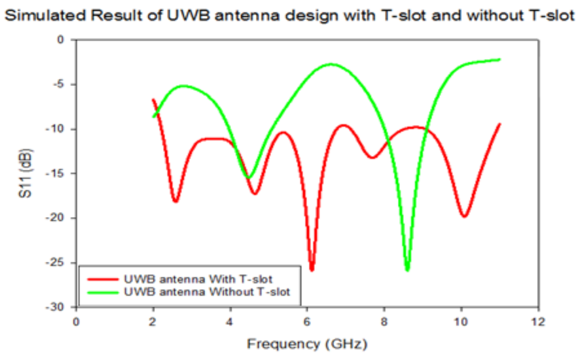


Fig. 2: Comparison of simulated reflection coefficient (S11), between With T-slot and Without T-slot.

Figure 2 shows a reflection coefficient comparison between UWB embroidered antenna without T-slot and with T-slot. The simulated result is plotted from 2GHz to 11GHz. It shows fluctuates pattern with a narrowband under the acceptable reflection coefficient of less than -10dB. Moreover, the impedance bandwidth is 2.47GHz.

Table 3: Comparison of Gain, Directivitiy and % Efficiency (a) First design of UWB embroidered antenna without T-Slots.

Frequency (GHz)	Gain (dB)	Directivity (dBi)	% Efficiency
3	4.079	4.075	73
4	4.042	4.051	93
5	3.624	3.661	90
6	3.342	3.436	63
7	4.778	4.899	57
8	5.384	5.479	92
9	5.219	5.336	89
10	5.347	5.515	52

(b) Second design of UWB embroidered antenna with T-slot.

Frequency (GHz)	Gain (dB)	Directivity (dBi)	% Efficiency
3	3.753	3.793	93
4	3.719	3.748	92
5	3.507	3.581	93
6	3.053	3.118	97
7	4.778	4.597	88
8	4.234	4.310	92
9	4.006	4.068	89
10	4.535	4.608	96

Gain is one of the significant parameters that can determine the performance of the antenna. Table 3 shows the variation of frequencies against directivity, gain and efficiency for both antennas. First design indicates the lowest gain of 3.342dBi at 6GHz while the highest gain is 5.384dBi at 8GHz. The highest efficiency is 93% at 4GHz while at 10GHz, the efficiency recorded the lowest value of 52%. Generally, some of the gains are more than 5dBi that depicted some frequencies using high power consumption. Therefore, some modification of the 1st design should be introduced to achieve low gain with large bandwidth and low power consumption that can cover up the entire frequency of UWB applications. The enhancement considered on the port width, partial ground and T-slot.

Antenna with T-slot achieved frequency range between 3GHz to 10GHz. Maximum gain of 4.778dBi is obtained at 7GHz while the minimum gain is 3.053dBi at 6GHz. The second design has 97% of highest antenna efficiency at 6GHz while the lowest efficiency is 88% at 7GHz. Overall, the average gain is less than 5dBi throughout the frequencies ranges from 3GHz to 10GHz. Thus, the antenna has low power consumption and meets the specifications of the design.

We must define some variables to formulate the problem. We know that in the network there is current traffic and arriving or requested traffic. Traffic can be static or dynamic, depending on the existing relations between the current and arriving traffic. It is dynamic when the average connection time of current traffic is much less than the average time between services request arrivals. This scenario is not optimizable, so heuristic

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algorithms are used, most of which offer greater solutions that are not necessarily optimum, but this richness provides much support when the contentions problem arises, avoiding a new execution of the algorithmic process. The problem is to establish the routes and the wavelength assignments in the network for various criteria, with minimum probability of blocking the requests, low transport latency along the route, low level of jitter, etc. The problem is known as RWA, Routing Wavelength Assignment (routing and wavelength assignment). Different strategies have been tested to satisfy the demand of an optical network, and optimization criteria and algorithms have been used. The optimization criteria have been based on:

Table 4: Current distribution for 1st and 2nd design.

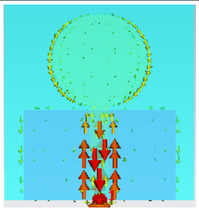
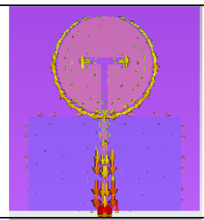
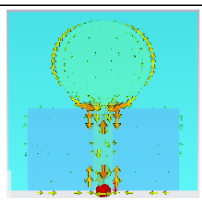
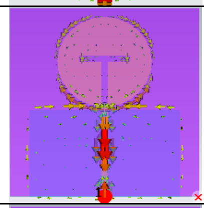
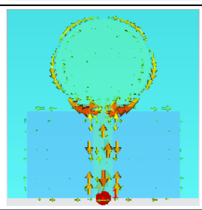
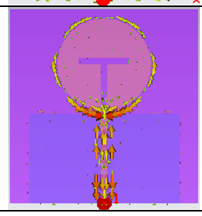
Frequency (GHz)	First design : UWB embroidered antenna without T - slots	Second design : UWB embroidered antenna with T- slot
3		
6		
9		

Table 4 presented the current flows for both antennas designed at different frequencies; 3GHz as low frequency, 6GHz as medium frequency and 9GHz as high frequency. High strength of current is radiating along the transmission line and the boundary of the patch after applying T-slot at the circular patch antenna. Moreover, the boundary of a partial ground plane also is a significant radiation area. Hence, the partial ground plane provides greater impedance bandwidth and used as low power consumption that suited the UWB applications. The UWB is achieved by considering suitable gap between partial ground planes and the antenna.

Conclusions:

This paper presents the development, fabrication and evaluation of the antenna's performance between frequency ranges of 3.1GHz to 10.6GHz. Two embroidered UWB antennas using cotton as substrate were considered . The investigation focussed on the performances of both antennas with and without T-slots. Based on the comparison of both designs, it shows that the antenna with T-slot achieved a better impedance matching with a wider bandwidth compared to the antenna without T-slot. In terms of gain and efficiency, the 2nd design provides low gain with better performance. The gain is less than 5dBi and basically used low power consumption. Hence, the modified 2nd design provides low gain, omni-directional pattern and used low power which suited the performance of the UWB specifications. Moreover, the antenna with T-slot has a high efficiency of data rate. Further work has been done in another conference paper that focusing more on the bending issue.

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