Dual-Band Bench Feed Textile Antenna

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1. Introduction

Nowadays, wearable antennas are widely used in several occupation segments such as for paramedics and fire fighters [1]. Wearable antenna has to be body conformal and not hindering the movement of the user. Therefore, wearable antenna have to be textile based antenna, made from conductive textile with several requirements such as low electrical resistance, flexible and can be deformed [2].

This paper presents two prototypes of textile antenna for WLAN Wireless Local Area Network and HiperLAN (High Performance Radio LAN). Introduction of shorting pin o the second prototype helps to shift the frequency to achieve desired resonant frequency without adjusting the dimension of the antenna. Both prototypes has been fabricated, measured and analyzed. The antenna prototype can be worn, as the entire materials used in fabricating the antenna are textiles. Felt with 1.3 mm thickness used as substrate while Zelt Conductive Fabric with 0.0635 mm used as radiating element. Overall thickness of the proposed antenna is only 1.427 mm, still consider as thin layer and comfort to be worn.

2. Antenna Design

The proposed design is carried out using CST Microwave Studio Software (MWS). The desired design frequencies are set to be at 2.45 GHz, 5.2 GHz and 5.8 GHz. In order to model the conductive textile, the conductivity of the textile material has to be determined from the thickness and the surface resistance of the textile, using the following equation [3]:

$$\sigma = \frac{1}{R_s \times t} \qquad (1)$$

Where R_s = surface resistance of the material, t = thickness of the material and σ = conductivity of material. The substrate used in the proposed antenna design is 1.3 mm felt composed from 100% acrylic fiber. Its substrate and thickness is chosen in order to ease antenna-clothing integration in practical applications. On the other hand, the conductive textile used as the radiator is made from Zelt conductive fabric having 0.0635 mm of thickness and conductivity of 1.75 x 10^5 S/m. It is a woven conductive fabric made from high quality nylon taffeta fabric, which is then copper and tin plated. This silvery textile holds a surface resistivity of less than 0.05 Ω/square.

In this investigation, two version of the proposed antenna is fabricated. Figure 1(a) shows the top view and Figure 1(b) shows the bottom view of the proposed antenna. The proposed antenna is symmetrical with the central line of the ground plane, with an overall dimension of 100 x 120 mm. Size of the ground plane effects many of the antenna's characteristic such as impedance width, impedance matching, radiation pattern, gain and impulse response [4-6]. For the proposed design, the narrow 40 x 100 mm ground plane at the bottom of the antenna is designed to enhance its impedance matching. The symmetrical arm functions as a dipole, resonating at 5 GHz, while a tuning stub is introduced at the center of the cross-junction to ease impedance tuning for the 2.45 GHz band.

In the second prototype, the same materials and antenna dimensions are used; the only difference is that a parasitic pin is added at the middle of the tuning stub to short the radiating patch and the ground plane. Experimental result shows that introduction of the parasitic pin helps to shift the frequency to desired frequency without adjusting the other dimension of the antenna. The design is shown in Figure 3. Fabrication of the textile antenna is carried out using hand cut tools. Thus, cutting is done with extra precaution as any imprecision will affect the resonance of the antenna designed. However, the simple textile antenna design has simplified fabrication, in which the smallest dimension edge is 5mm. The proposed fabricated antenna is shown in Figure 2.

3. Results and Discussion

Both proposed prototypes are seen to produce a dual-band S11 response, at both 2.4 GHz and 5.8 GHz. For preliminary prototype 1 (without the shorting pin), it can be seen that the simulated antenna resonated at a higher frequency of 3.3 GHz and 5.1 GHz. This shows that the antenna should have a larger dimension area in order to resonate at the lower desired frequency of 2.45 GHz. Its bandwidth, 200 MHz and 1360 MHz, respectively, is enough for the antenna to operate at both 2.4 GHz and 5.2 GHz with some tuning using the stub. Its measured center frequency (fc), however, produced frequency shift upwards, at 3.6 GHz, with a bandwidth of 400 MHz. The upper frequency produced two bands, centered at 5.08 GHz and 6.12 GHz, with 900 MHz and 640 MHz of bandwidth, respectively. It can also be observed that the measured prototype is producing almost twice the simulated bandwidth at the lower frequency, even in the event of frequency upwards shift.

For prototype 2, the addition of the shorting pin is seen to have enlarged the effective size of the antenna. Abrupt current flow introduced by the shorting pin has introduced new current paths between radiator and ground plane, shifting the frequency lower to achieve the desired frequency. The impedance change using the pin produced a 500 MHz simulated bandwidth, from 1.90 GHz to 2.40 GHz at the lower band. On the other hand, simulation results indicated that the effective antenna operating frequency is between 4.88 GHz to 5.96 GHz, a huge 1 GHz bandwidth covering both 5.2 GHz and 5.8 GHz bands. Measurement of S_{11} produced excellent agreement with simulation, contrary to the previous prototype. However, similar trends are experienced in the improvement of the bandwidths, both at lower and higher bands. The bandwidth almost doubled, from 500MHz to 1080 MHz at 2.4 GHz band when simulation and measurements are compared. Examining the upper bands of 5.2 and 5.8 GHz, on the other hand, the large bandwidth is divided into two parts instead of one, which is predicted by simulation. A large bandwidth of over 1 GHz centered at 5.42 GHz is transformed into two 600 MHz bands centered at 4.90 GHz and 6.1 GHz. Nonetheless, this division did not affect the operation of the antenna, which was initially designed for operation in the 5.2 GHz and 5.8 GHz bands. Simulation and measurement results are summarized in Figures 4 and 5, and Table I.

In analyzing the results, several observations can be drawn. It is seen that the antenna actually resonated at a higher frequency in comparison to simulated results. At the lower frequency, a doubling of the bandwidth is also experienced. On the other hand, at the upper frequency, the large simulated bandwidth is seen to be split into two parts. Addition of the shorting pin has effectively changed the current path, making the antenna larger than it is physically and shifting frequency downwards.

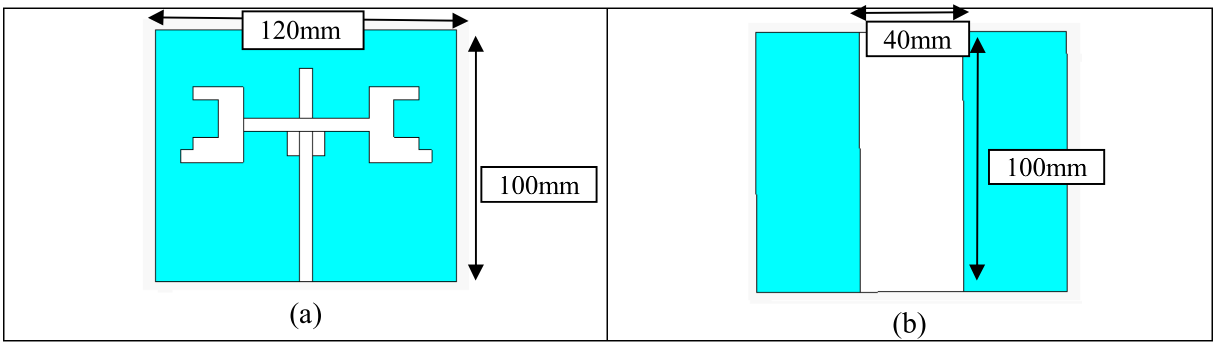

Figure 1: The proposed antenna (prototype 1): (a) Top view; (b) Bottom view

Figure 2: The fabricated antenna (prototype 1): (a) Top view; (b) Bottom view

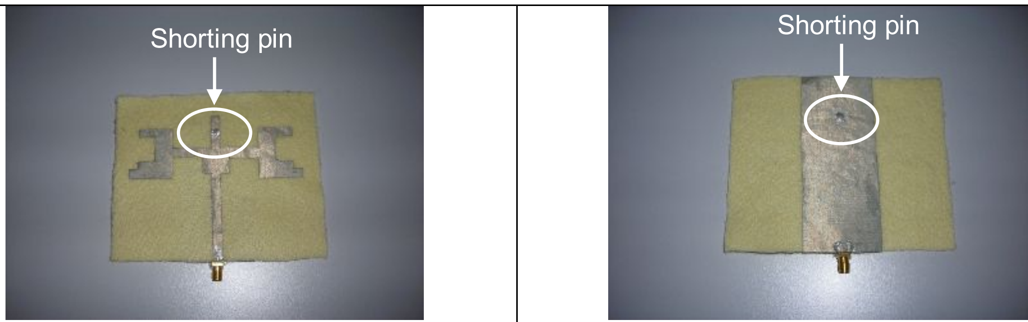

Figure 3: The fabricated antenna (prototype 2): (a) Top view; (b) Bottom view

Table 1: Simulated and measured S_{11} for both prototypes

Prototype No		Center freq (GHz)	Calculated Center freq (GHz)	Bandwidth (GHz)	Bandwidth (MHz)
1	Sim	3.30	3.24	3.14 – 3.34	200
		5.10	5.30	4.62 – 5.98	1360
	Meas	3.60	3.60	3.4- 3.8	400
		5.08 6.12	5.05 6.12	4.60 – 5.50, 5.80 – 6.44	900 640
2	Sim	2.40	2.15	1.90 – 2.40	500
		5.00	5.42	4.88 – 5.96	1080
	Meas	2.40	2.505	2.00 – 3.01	1010
		5.00 6.05	4.90 6.10	4.60 – 5.20, 5.80 – 6.40	600 600

Table 2: Simulated gain, radiation efficiency and total efficiency for both prototypes

	Prototype 1		Prototype 2	
Frequency (GHz)	2.45	5.00	2.45	5.00
Gain (dB)	-0.68	3.10	2.57	3.60
Radiation Efficiency (%)	34.00	83.00	84.00	82.00
Total Efficiency (%)	10.00	78.00	69.00	76.00

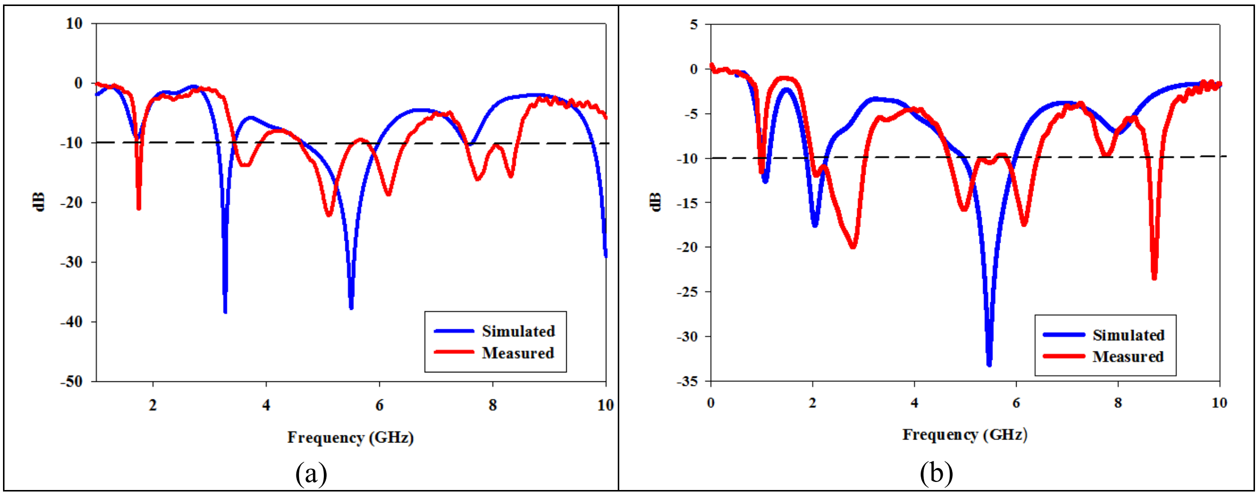

Figure 4: Simulated and measured S11 for: (a) Prototype 1; (b) Prototype 2

Table 2 summarizes the simulated gain, radiation efficiency and total efficiency at center frequency of the proposed antenna (at 2.45 GHz and 5.0 GHz). As shown in the table, performance of the antenna with addition of shorting pin is very much improved; since adding the shorting pin is similar to adding an inductance to the patch [7]. The better matched prototype 2 showed a significant improvement in gain and efficiency at 2.45 GHz.

4. Conclusions

Two prototypes of a bench fed textile antenna has been simulated, fabricated and analyzed. The better performing prototype 2 emphasized the validity of using shorting pins to enhance performance of a textile antenna. While both prototypes produced a doubling of bandwidth at the lower frequency of 2.4 GHz, the additional inductance, improved matching at the higher frequency of 5.2 GHz and 5.8 GHz.

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