Textile Bowtie Patch Antenna for Potential RF Energy Harvesting Application at GSM 1800

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Textile Bowtie Patch Antenna for Potential RF Energy Harvesting Application at GSM 1800

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Abstract. This paper presents the design and development of a textile bowtie patch antenna for potential RF energy harvesting application using the Global System for Mobile Communication (GSM 1800) band. The size of the antenna is 80 mm x 40 mm, and is designed on a 6 mm thick Felt textile as the substrate and 0.08 mm-thick ShieldIt as its conducting material. The simulated and measured reflection coefficients justified that the bowtie antenna can be used for RF energy harvesting application at 1.8 GHz. This antenna has realized gain ranging from 2.56 dB to 2.55 dB and a total antenna efficiency of -4.3 dB.

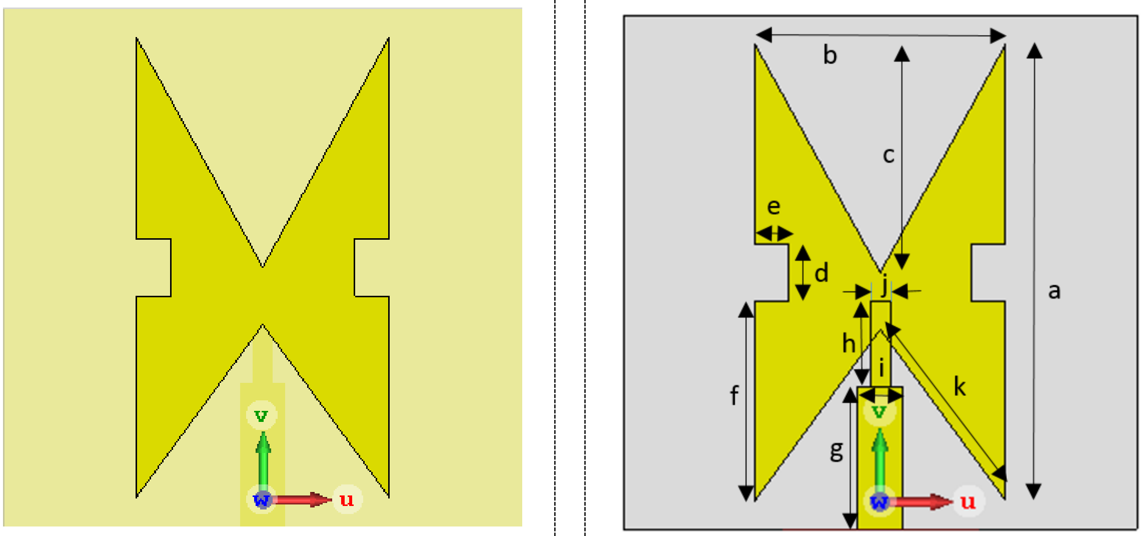
1. Introduction

Recently, there is growing popularity in the use of wearable devices such as in health monitoring, security services, emergency rescue application, sports and entertainment. These wearable devices are small, low-powered and lightweight. In order to increase the battery lifetime of these devices to ensure continuous and autonomous operation, there is a need for them to be integrated with energy harvesting mechanism. Energy harvesting has attracted much attention in research for the last decades with many types of energy harvesting technologies are available in the market. One of the promising energy harvesting technologies is the RF energy harvesting. Due to the existence of abundant ambient RF signals that have the ability to penetrate buildings, there is great opportunity for the RF signals to be harvested to generate sufficient power to power up low-powered wearable devices. One of the main challenges for the far-field RF energy harvesting is to overcome the losses due to long distance and obstacles in between the transmitter and the receiving antenna [1], which is an essential part of the RF energy harvesting building block. Thus, the antenna must possess high gain and high efficiency to receive the weak RF signals from the surrounding.

In recent years, various receiver antennas for RF energy harvesting antennas have been proposed including Yagi-Uda antenna [1-2], bow-tie antenna [3] and dipole antenna [4]. However, few researches have focused on textile antenna for RF energy harvesting. Among the papers are, in [5] Yagi textile antenna at 60 GHz was developed with the measured antenna gain about 9 dBi and radiation efficiency of 74%. A UHF wearable patch antenna was developed in [6] with measured gain of 4.6 dBi and antenna efficiency of 41.4%. While in [7], the textile Yagi antenna on jeans fabric with the gain of 6.32 dBi to 7.26 dBi and radiation efficiency from 90.52% to 91.34% has been simulated, respectively.

2. The design of a bowtie patch antenna

The bowtie dipole antenna is chosen due to its small size, lightweight, design simplicity and low cost. In this work, a bowtie patch antenna for RF harvesting application is designed at 1.8 GHz and simulated in CST Studio Suite. The antenna is then fabricated and assessed. The size of the antenna is 80 mm x 40 mm. The substrate used for this antenna is Felt textile with relative permittivity of 1.45, a thickness of 6mm and loss tangen (tanδ) of 0.044. Generally, low dielectric constant substrates are preferred for maximum radiation [9]. The ground can take any shape but the most common shape used are rectangular and circular. Meanwhile, the conducting material used is ShieldIt with a thickness of 0.08 mm and a conductivity (σ) of 1.8×10^5 S/m. For simplification in simulations, ShieldIt is considered as lossy material [8]. A waveguide feed has been designed on the antenna in order to connect to 50Ω SMA connector. Figure 1(a) and 1(b) illustrates the dimension of the bowtie patch antenna and top view of the bowtie patch antenna respectively. The antenna parameters and dimensions are as summarized in Table 1. The top view of the fabricated antenna is shown in figure 2.



(a) (b)

Figure 1. (a) Dimensions of the bowtie patch antenna (b) top view of the bowtie patch antenna

Table 1. Antenna parameters and dimensions.

Parameter	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*
Dimension (mm)	80	44	40	10	5.5	35	25	15	8.8	3.5	30

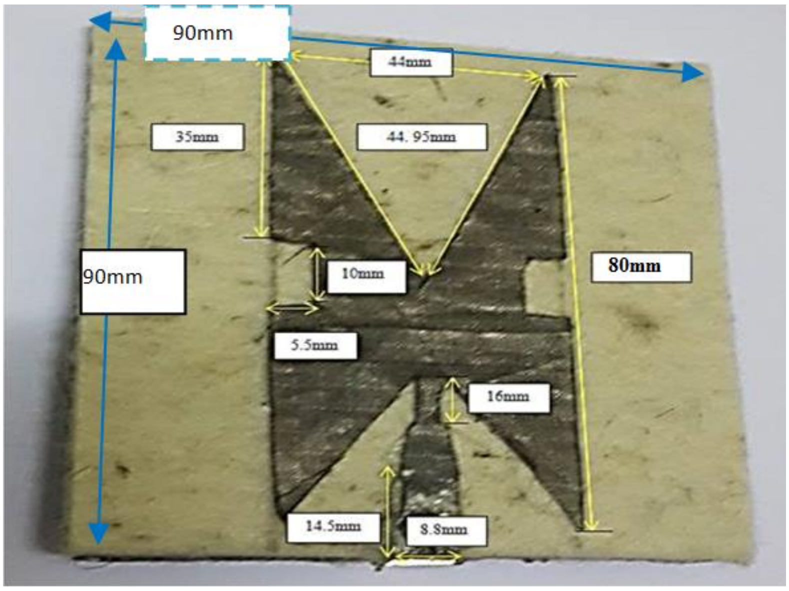
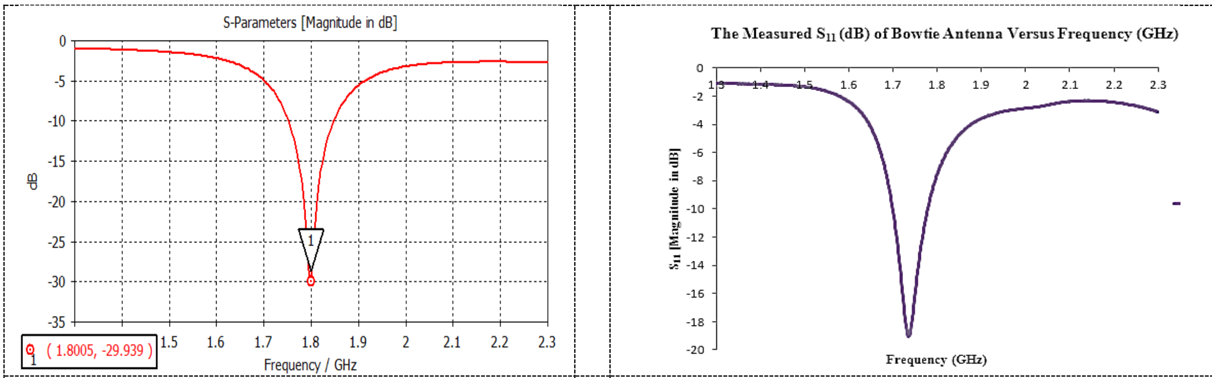


Figure 2. Top view of the fabricated bowtie patch antenna

3. Results and Discussions

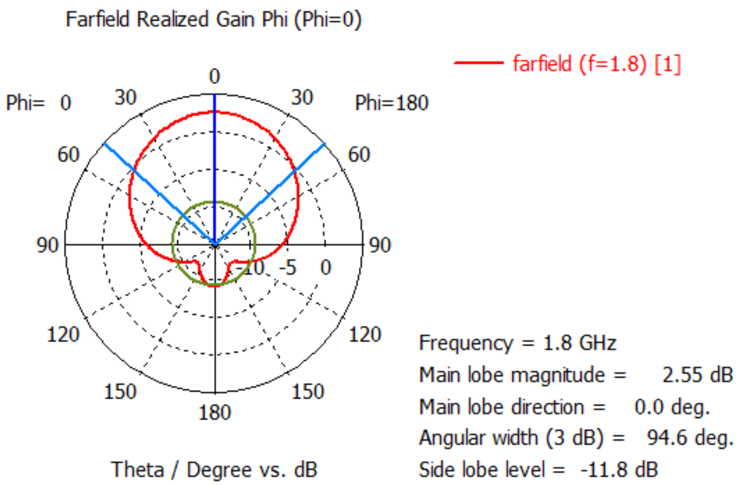
All simulations have been performed using CST Studio Suite and the fabricated bowtie antenna have been tested using Vector Network Analyzer (VNA) to verify the simulation result. Figure 3(a) and 3(b) shows the simulated and measured reflection coefficients versus frequency for the textile bowtie antenna, respectively. The simulated reflection coefficient shows that the antenna is working well at 1.8 GHz, but the measurement shows slight deviation of the resonant frequency to 1.74 GHz due to the larger tolerance of fabrication when using manual cutting tools. Besides that, the ShieldIt conducting fabric is not perfectly attached to the felt substrate resulting in small air gaps. Moreover, the misalignment and soldering of the SMA conductor causes the deviation in the resonant frequency.



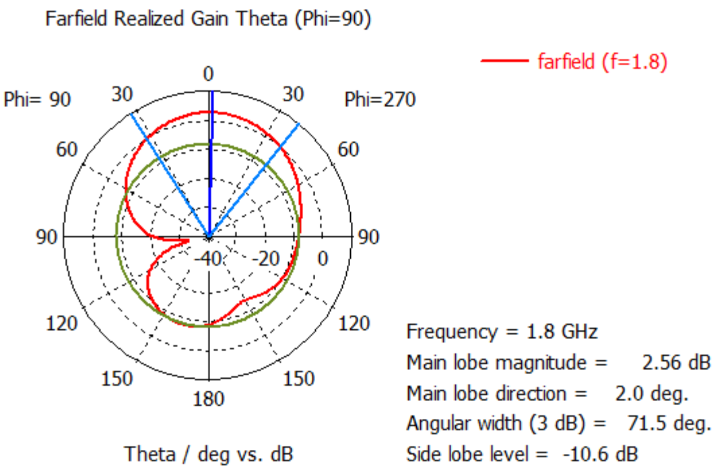
(a) (b)

Figure 3. (a) The simulated reflection coefficient versus frequency (b) measured reflection coefficient versus frequency

The simulated radiation pattern of the antenna at 1.8 GHz is as illustrated in figure 4(a) and 4(b) respectively, at $\varphi = 0°$ and $\varphi = 90°$ cuts. The antenna has half-power beamwidths of 94.6° at phi = 0° and 71.5° at $\varphi = 90°$, while the far-field realized gains of 2.55 dB at $\varphi = 0°$ and 2.56 dB at $\varphi = 90°$. The radiation efficiency and total antenna efficiency is as depicted in Figure 5(a) and 5(b), respectively.

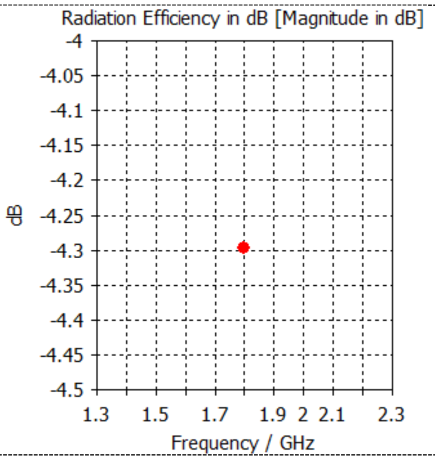


(a)

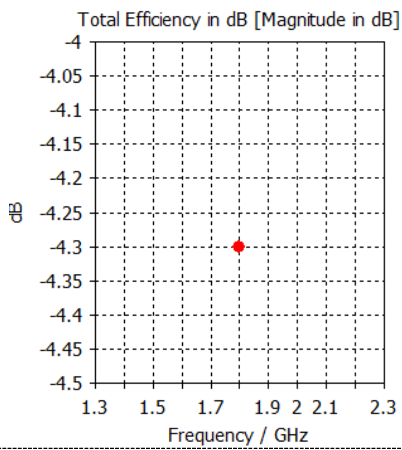


(b)

Figure 4. (a) Radiation pattern at $\varphi = 0°$ and (b) at $\varphi = 90°$.



(a)



(b)

Figure 5. (a) Radiation efficiency (b) total efficiency of the bowtie patch antenna

4. Conclusions

The simulation and measurement results have validated that the textile bowtie patch antenna in this work is operating at 1.8 GHz, despite some deviation in measured performance caused by fabrication tolerances. The performance indicated that this antenna is suitable for RF energy harvesting application at GSM band since it has sufficient realized gain of 2.55 dB and 2.56 dB at $\varphi = 0°$ and $\varphi = 90°$ respectively, and a total antenna efficiency of -4.3 dB.

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