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# Printed Rectangular Monopole Antenna for Applications at 2.45 GHz and 3.5 GHz

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**ABSTRACT:** A printed rectangular monopole antenna is proposed for textile application satisfying wireless applications. The antenna is design on FR4 substrate using copper sheet as the radiating element and ground plane. Ground plane of the proposed antenna is replaced with a stitched ground on Denim substrate. Embroidery is used to achieve the fabrication of the ground with the aid of conductive thread Amber strand. CST Microwave studio software (2019) is used for simulation and design of the proposed antenna. Measured results were compared with the simulation and good agreement is shown. The impedance bandwidth -10 dB indications that the proposed antenna could be implemented as wearable antenna because the wide bandwidth.

**KEYWORDS:** Embroidery, Stitched ground, Printed monopole, Bandwidth, Denim substrate.

## I. INTRODUCTION

Printed monopole antenna (PMA) is used for wireless communication service because its advantages; large impedance bandwidth, omni directional radiation pattern to communicate with radio element whatever their position is and ease of integration with electronic circuitry. This antenna is designed to meet the characteristic of wireless services, that are simple feeding, low profile, and low fabrication cost. Many researchers have studied various configurations and geometries of the planar monopoles, these include rectangular, square, circular disc square, trapezoid, triangular, elliptical, hexagonal, and planar disc [1-5]. The PMA is form of microstrip antenna where the ground is located at infinity [1]. The feed to Printed monopole antenna is a microstrip line through direct connection. Radiation pattern of PMA is similar to dipole antenna.

The proposed printed monopole antenna could use for these applications; Wireless local area network (WLAN: 2.4-2.484 GHz), Mobile worldwide interoperability for microwave access (WiMAX:2.5-2.69 GHz) and (3.4 -3.69 GHz) [3]. In this work, a printed rectangular monopole antenna was examined with the possibility of integrating an embroidered ground plane using conductive thread (Amber strand) onto a denim substrate. Result for the single layer denim are thickness 0.85mm  $\epsilon_r = 1.97 \tan \delta = 0.07$  that was used for the ground plane. The rectangular configuration was designed because of the ease of fabrication using computer embroidery. The ground plane design was exported as a graphic format on a drive and sent to the digital embroidery machine at Loughborough University. The ground plane is embroidered using a multi strand conducting Liberator™ with a conductor of silver. The yam has 66 polymer threads with  $1\mu\text{m}$  silver coating on each thread [6].

## II. ANTENNA DESIGN AND STRUCTURE

Figure 1 shows the geometry of the proposed printed monopole antenna. The structure is fabricated on FR4 substrate with thickness of 1.4 mm. having a relative permittivity of 4.4. The proposed design was simulated using Finite Integration Technique (FIT). The dimensions of the printed monopole antenna were estimated using equations from [1-3]. The lower frequency ( $f_L$ ) was calculated for VSWR = 2 is given as [1], using equations (1) – (2).

$$L = 0.24\lambda F \quad (1)$$

Where  $F = L/(L + r)$  and  $r = W/2\pi$

$$f_L = c/\lambda = 7.2/(L + r + p) \times k \quad \text{GHz} \quad (2)$$

Where  $L$  is the length of the planar monopole antenna in mm,  $r$  is the effective radius of an equivalent cylindrical monopole antenna and  $p$  is the probe length (50  $\Omega$  feed line) are in mm.  $K$  is given as  $\sqrt{\epsilon_{eff}}$  because of the FR4 (with

thickness of 1.6mm) dielectric layer with  $\epsilon_r = 4.4$ . FR4 was chosen as a dielectric substrate because of material properties and its low cost. The PMA was fabricated after carrying out a few simulations in CST Microwave Studio. A printed rectangular monopole antenna with dimension  $L = 14 \text{ mm}$ ,  $W = 18 \text{ mm}$ ,  $p = 33 \text{ mm}$ , and ground plane ( $28 \text{ mm} \times 30 \text{ mm}$ ) simulated  $f_L = 2.198 \text{ GHz}$  and measured  $f_L = 2.162 \text{ GHz}$  was designed, simulated and measured.  $f_L$  increases from 2.198 GHz to 4.556 GHz.

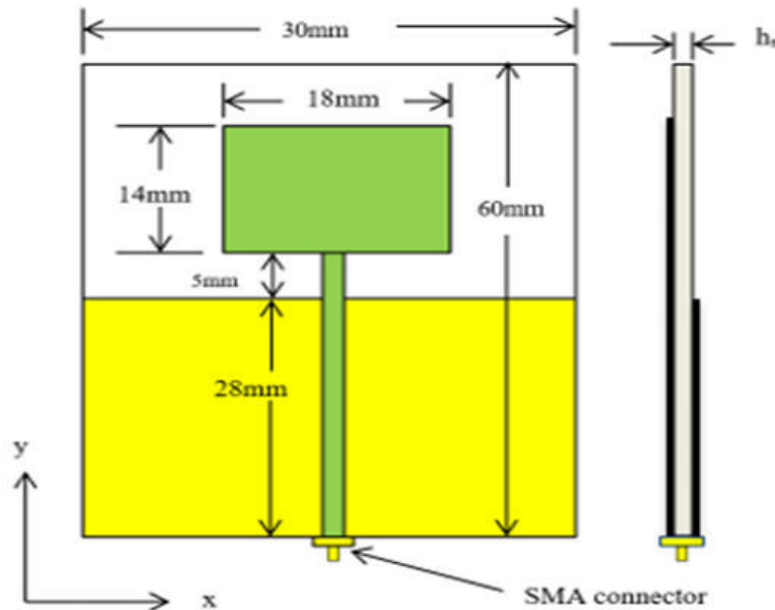


Figure 1 Geometric structure of a printed monopole antenna.

This designed antenna was fabricated taking advantages of printed circuit board (PCB) and embroidery techniques. Figure 2 was fabricated and tested in the Wireless Communication Laboratory at the Loughborough University and the reflection coefficients were measured using a 37397D Vector Network Analyzer to verify the theoretical analysis. The zigzag stitch pattern was used to design the ground plane, number of stitches used to realize the design is 1224. Based on the prototype design parameters, computer embroidery machine was used to stitch the design on to a denim substrate.

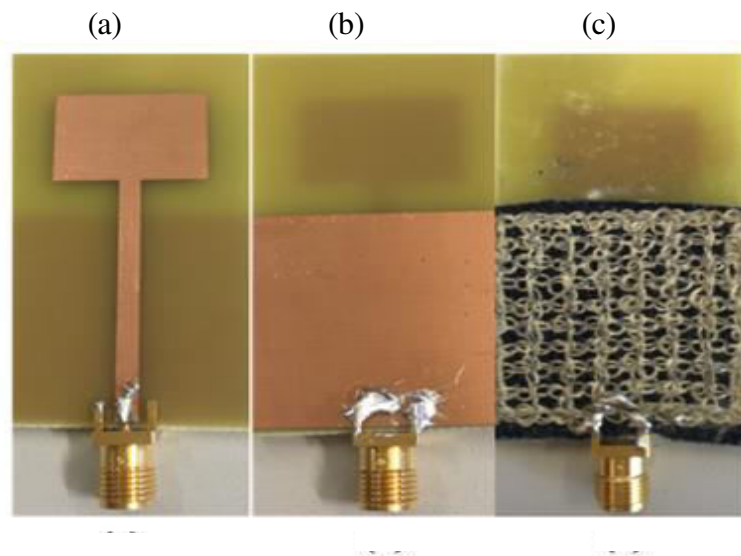


Figure 2 Fabricated antenna (a) Front (b) copper ground (c) Embroidered ground

III. PREDICTED AND MEASURED RESULTS

The reflection coefficient ( $S_{11}$ ) is a measure of the power reflected from the antenna. Figure 3 shows the simulated and the measured reflection coefficient plots of prototype antenna design. Resonances of 2.527 GHz at -35.75 dB, 2.848 GHz at -38.33 dB, 3.106 GHz at -16.88 dB, 3.238 GHz at -28.23 dB and 4.272 GHz at -24.01 dB were observed. The measured -10 dB reflection coefficient bandwidth is from 2.162 to 3.655 GHz with solid ground plane, on embroidered ground plane measured -10 dB  $S_{11}$  bandwidth is from 2.623 to 3.622 GHz and in simulation of the solid ground plane from 2.198 to 4.556 GHz.

The surface current distribution on the proposed PMA at 2.45 GHz is shown in Fig. 4. Current distribution on the radiating element is distributed along the edges of the feed line at first resonance. The maximum current is within the feed point 30 A/m. Good radiation patterns were obtained at 2.45 GHz and 3 GHz.

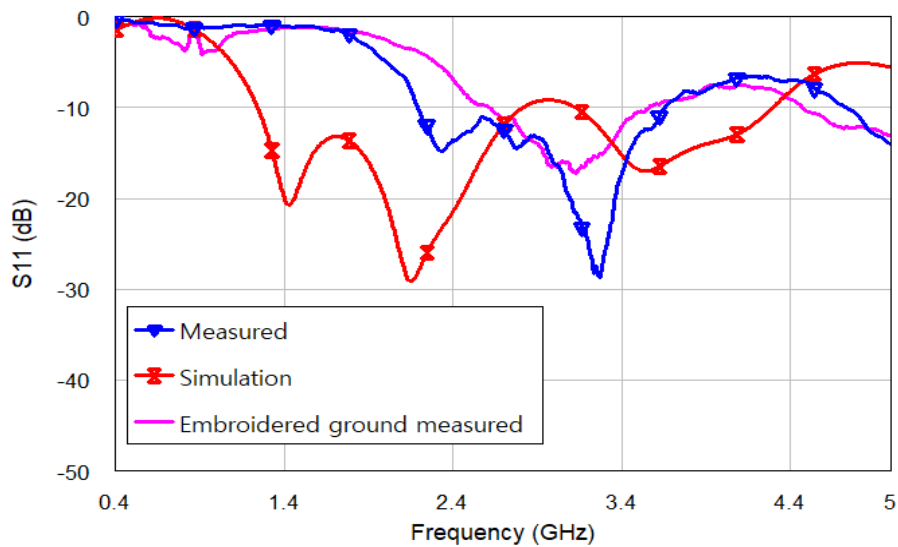


Figure 3 Simulated and Measured  $S_{11}$  result of the proposed antenna on stitched ground plane.

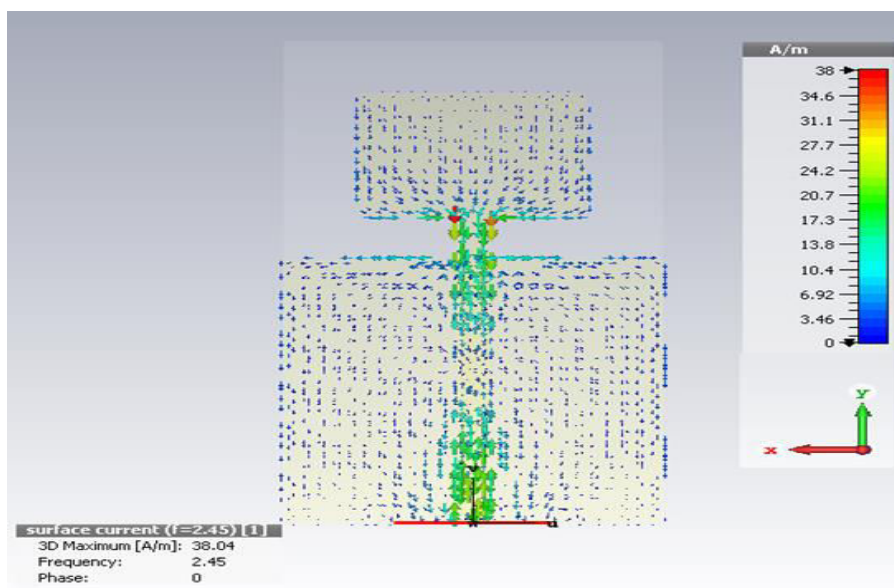


Figure 4 Simulated surface current distribution for the proposed antenna at 2.45 GHz

The simulated 3-D far field pattern, which controls the antenna's radiation pattern, is illustrated in Fig5. As can be indicated from the figure, the region with the highest gain of 4.55 dB is coming from the radiating element of the antenna and slowly settles down to 0dB further away from the radiating structure. The 3-D far field pattern has most of the power radiated is distributed in the y-z plane with a maximum gain of 4.55 dB, at 2.45 GHz and 3.5 GHz, then power is less concentrated in the x-y plane

(a)

(b)

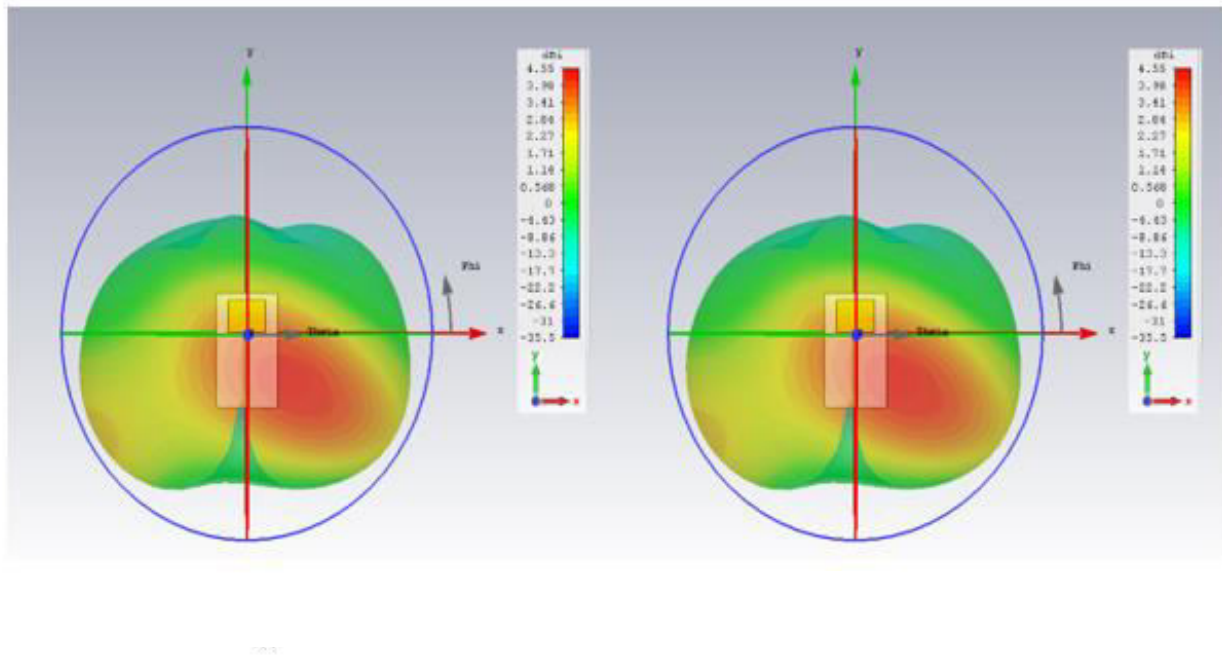


Figure 5 Simulated 3D radiation pattern for the proposed antenna (a) at 2.45 GHz and (b) at 3.5 GHz

#### IV. CONCLUSION

Impedance bandwidth of 51.3 % ranging from 2.162 to 3.655 GHz, bandwidth of 29.8 % ranging from 2.623 to 3.543 GHz and 69.8 % ranging from 2.198 to 4.556 GHz for  $S_{11} < -10$  dB are achieved. Theoretical results have been validated with measurements shows good agreements. The structure of the proposed antenna could equally be replaced with fully textile materials, but the only ground plane was achieved using the embroidery technique.

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