# A Wideband Antenna Based on Composite Flexible Substrate for Wearable Application

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## Abstract

The design and characterization of a simple, flexible wideband antenna using Polydimethyl-siloxane (PDMS) composite is presented. Conductive fibers are used to construct the metallic parts on a PDMS composite. To characterize the performance, two identical antennas are designed, one using the PDMS composite while the other on conventional dielectric materials. The antenna exhibits a matched bandwidth of 59.9%, ranging from 3.43 to 11.1 GHz. With excellent performance and high flexibility, this antenna is well-suited for body area networks and other wearable applications.

## 1. Introduction

Flexible antennas have promising applications in healthcare monitoring, sports, rescue and public safety. Robustness of antenna to withstand dynamic operating conditions is a highly-sought characteristic for such applications. Conventional approach for fabricating antennas is based on etching metal patterns on rigid dielectric-based substrates. The antennas resulting from this process are susceptible to permanent deformation or even breakage when undergoing bending or twisting. Flexible antennas made out of copper tape and conductive ink on flexible substrates have been reported in the past [1-3]. However, copper-based designs were rigid and conductive inks are not suited for long term use due to peeling.

Conductive fibers on textiles and polymer composite substrates have been used to overcome these limitations [4-6]. A dual-band textile antenna on Polydimethyl-siloxane (PDMS) substrate is reported in [5] and is evaluated against its rigid version [7]. Textile antennas were demonstrated for body-worn communications and medical sensors with comparable performance to their rigid counterparts [6]. But all these antennas present narrow bandwidth. This paper presents and characterizes a wideband antenna designed on a flexible substrate. Two antennas are constructed using the same design parameters. The first antenna is fabricated using classical etching process on dielectric substrate Rogers RO3003. The second is constructed by embroidering metallic patterns using conductive thread on a thin layer of fabric, and afterwards, placing on a the PDMS composite during the curing phase.

## 2. Antenna Layout and Design

Fig. 1 shows the geometry of the printed wideband antenna. This antenna is a monopole radiator and formed by extending a microstrip line. The wideband radiation is achieved by a patch with chamfered corners at the lower sides and a rectangular slot in the middle. It is fed by a 50-ohm microstrip line. The antenna uses a partial ground plane below the mictrostrip line and a slot is placed beneath the feed point to tune the impedance matching. The design parameters of the antenna are shown in Fig. 1.

Initial design and analysis of this antenna was carried out in ANSYS HFSS. Full-wave analysis shows that the antenna is able to cover the entire UWB range, and has a matched impedance bandwidth from 3.43 GHz to 11.1 GHz. To characterize the performance of this antenna using a composite, flexible substrate, two versions of this monopole radiator were fabricated. First version of the antenna uses Rogers RO3003, with dielectric constant $\varepsilon = 3$, loss tangent $\tan\,\delta = 0.001$. The second version was embroidered and placed on a PDMS substrate. The PDMS composite substrate had a dielectric constant $\varepsilon = 3$, loss tangent $\tan\,\delta = 0.01$. Both substrates were 1.524mm thick.

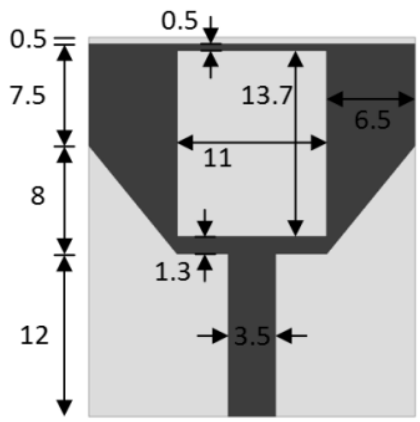
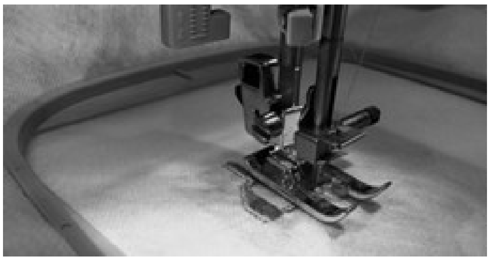
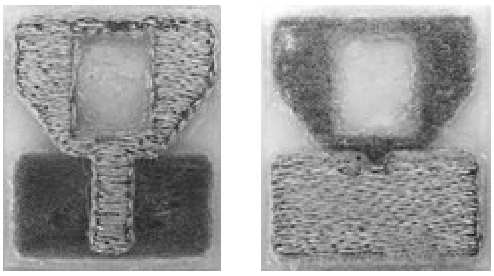



**Figure 1.** Layout of the antenna with design parameters in millimeters.



(a)



(b)

**Figure 2.** (a) Embroidery process of metallic antenna parts using conductive thread, (b) Fabricated prototype of the flexible antenna on PDMS substrate.

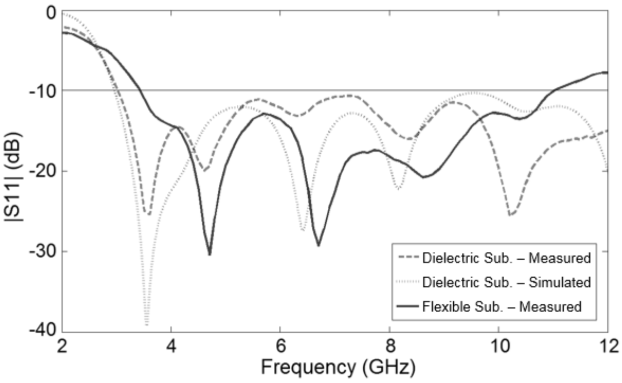



**Figure 3.** Comparison of measured reflection coefficient of the antennas fabricated using classical dielectric-based substrate and composited PDMS substrate.

Sylgard 184 PDMS was used in the fabrication process and the process of polymer fabrication was adapted from [8] and [9]. PDMS was chosen due to its mechanical flexibility, water resistance and inherent chemical stability [8]. It was made manually by mixing the monomer and the curing agent using a ratio 10:1. The air bubbles were removed before curing, as they can effect the dielectric constant of the cured substrate. The mixture was subsequently heated and dried using a hot plate.

The antenna was constructed by embroidering on organza fabric using LiberatorTM 20 conductive fibers. LiberatorTM 20 has a DC resistance of 2 ohm/ft. Each thread consists of 20 filaments, each coated with silver and bound together into a single thread. The embroidered parts were placed on wet PDMS, and then cured. The curing process took several hours and sealed the embroidered antenna into the polymer coating.

## 3. Results

The copper and textile prototypes were measured and the corresponding reflection coefficients are given in Fig. 3. The antenna using RO3003 substrate demonstrates a matched bandwidth ($|S_{11}| > -10$dB) from 3.1–10.6GHz. The textile antenna on PDMS substrate demonstrates a corresponding bandwidth of 3.43–11.1GHz. A small shift can be observed for the textile antenna at the lower bound of bandwidth. This can be attributed to a slight reduction of electrical length of the antenna, since sharp edges cannot be perfectly embroidered as compared to copper etching. A similar mismatch can be observed at the upper bound as well due to misalignment of the slot in the ground plane with the metallic radiating part on the top surface. The misalignment is caused by lack of preciseness in manual placement of metallic layers on the PDMS composite, before the sealing phase. Other than the corner cases, both antennas demonstrated good agreement over the entire bandwidth. The radiation patterns of these antennas are compared in Fig. 4, which also show good agreement between the two.

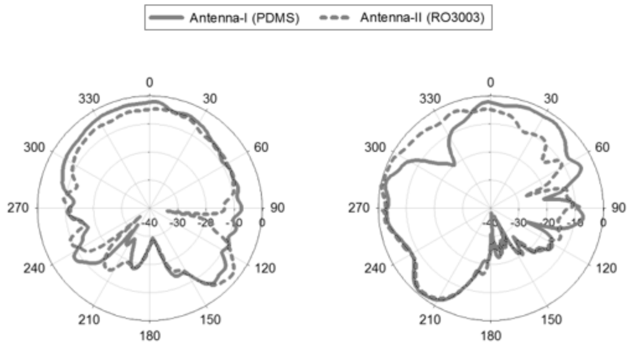



Figure 4. Measured radiation patterns at 3.5 GHz (a) $\phi = 0$ degrees, and (b) $\phi$=90 degrees.

## 4. Conclusion

The design and characterization of a simple, flexible wideband antenna using Polydimethyl-siloxane (PDMS) composite was undertaken, demonstrating that PDMS-based substrates can provide reasonable performance, in comparison to dielectric-based substrates. The flexible antenna using PDMS-substrate demonstrated a matched bandwidth of 59.9%, ranging from 3.43 to 11.1 GHz, covering the entire UWB band.

## 5. References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