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A Multi Stub Polygon Shaped Textile Antenna for Deformation Performance Using Aperiodic DGS

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ABSTRACT- A compact fully flexible antenna with 1.22 as dielectric constant with 0.016 loss tangent is designed for wearable biomedical applications. It has dimensions of 40.5 x 23 x 0.97 mm^3. The polygon-shaped patch is modified to achieve ultra-wideband frequencies using partial ground as 16.5mm and a periodic vertical slot of 13x2 mm^2 structure in defected ground structure to enhance the wide bandwidth of 2.6-11.1 GHz. Using a transmission line equation and a microstrip line feeding method, the resulting antenna operates at a biomedical frequency in open space and on the body-worn case with multi band *i.e.* 3.1 and 5GHz. The deformation process works well for the proposed antenna without affecting its actual bandwidth with 20 to 60 mm radii. Additionally, the proposed antenna operates at 5GHz for Wi-Fi with 3.67dBi gain, -35.1dB as S_{11} which is suitable for commercial applications. CST Microwave Studio was used to simulate the antenna and fabricate it for testing.

General Terms: Textile antenna for wireless body area network at ultra-wide band frequency for biomedical applications.
Keywords: DGS, Flexible Fabric, Microstrip Antenna, UWB, WBAN.

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1. INTRODUCTION

In wireless communication systems antennas are one of the basic components since they are a key component in the transmission and reception of data. Different antennas are used in modern communication to transmit and receive data for portable wireless devices, radar applications, bio-medical applications, and more [1]. Because of their inexpensive cost and ease of construction, microstrip patch antennas (MPAs) are popular for a variety of applications. Antennas of this type are commonly employed in biomedical applications [2].The Antenna is placed on the human body's surface. The foremost restrictions of the MPA's are the single working frequency with narrow bandwidth, size of the antenna, and low gain. The constraints of MPA are addressed using a variety of ways. Furthermore, the microstrip patch antenna array structure is used to achieve multi-band operation, and a novel DGS is used as the ground to increase the antenna's performance. The federal communications commission (FCC) allowed the viable usage of frequency bands for ultra-wideband systems ranging from 3.1 to 10.6 GHz when it first introduced ultra-wideband in 2002. The UWB antennas can be used to cover mobile and wireless services [3-5] while also reducing system complexity by reducing total device size and cost. The fundamental goal of the antenna design is to increase performance and gain while maintaining high radiation efficiency at UWB.A unique ultra-wideband wearable antenna for electronic-textile applications with a permittivity of 1.45 and operating at the frequency of 3.1-11.3GHz UWB was developed utilizing a permittivity of 1.45 for felt material and operates at the frequency of 3.1-11.3GHz UWB. An ultra-wideband monopole antenna base on DGS 2021[6]. [7] discussed about a system, a low power area reduced and speed improved serial type daisy chain memory register also known as shift Register is proposed by using modified clock generator circuit and SSASPL (Static differential Sense Amplifier based Shared Pulsed Latch). This latch-based shift register consumes low area and low power than other latches.

There is a modified complementary pass logic based 4-bit clock pulse generator with low power and low area is proposed that generates small clock pulses with small pulse width. The antenna was implemented with a cotton substrate with a permittivity of 1.4 that can function at frequencies ranging from 10.08 to 12.98 GHz and 2.59 to 6.67 GHz, backing up a variety of communication services in the X, C, S, and Ku bands with a gain of 7.4 dBi. In addition to resonance at 2.9 GHz, 9.1 GHz with a S11 of 34.84 dB, 33.74 dB, respectively, the proposed MCP antenna achieves an impedance bandwidth of 8.1 GHz (2.5–10.6 GHz) with a reflection coefficient reference line of 10 dB. Four dumble-shaped slots are used to increase antenna bandwidth and gain. The radius of a circular patch is determined by parametric analysis for UWB frequency tuning. [8]. The TNCPA with Defected Ground Structure (DGS) enables multiband and wideband operations within a single antenna

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structure [9]. Bed sheet cotton with a relative permittivity of 3.27 and a loss tangent of 0.00786 is used as the substrate material. This antenna measures 40x34x1.26mm [10] emphasized that people who are visually impaired have a hard time navigating their surroundings, recognizing objects, and avoiding hazards on their own since they do not know what is going on in their immediate surroundings. We have devised a new method of delivering assistance to people who are blind in their quest to improve their vision. An affordable, compact, and easy-to-use Raspberry Pi 3 Model B+ was chosen to demonstrate how the proposed prototype works Textile rectangle ring micro strip patch antenna using perforated (with small-sized holes) rectangular rings with a water vapor permeability of 5296.70g/m2, air permeability of 510mm/s, and radiation gains of 4.2dBi (E plane) and 5.4dBi (H plane). At a specified frequency of 2.45 GHz, the antenna resonates in the industrial, scientific, and medical band [11].

2. DESIGN OF ANTENNA AND METHODOLOGY

It employs a felt substrate with permittivity 1.2 and a thickness of 1mm, while the radiating patch is made of copper/nickel ripstop fabric. The purpose of designing of a novel antenna is to operate at ultra-wide band frequency with miniature in its appearance. The evolution of antenna has taken varies stages to achieve its frequencies with multi slots on its radiating element. Firstly, the substrate size is measured by using transmission line model equations where the patch is calculated; here the shape of the patch is a polygon which replicate as a octagon connected with a simple transmission line feeding technique is involved for stage one.

The basic method used in this proposed antenna is the transmission line model to measure the length and width of the antenna *figure 1 (a)* depicts a micro strip patch antenna [12-14]. MPA has dimensions of substrate (Felt) length L = 40.5mm, width W = 23mm, and height h = 0.97mm with permittivity = 1.22 and tangent loss = 0.016. It is placed on the antenna substrate and has a radius of R = 8.5mm. In terms of dimensions, the antenna has a length L1 = 16.57, a width W = 23mm, and a height h = 0.1mm. The octagonal patch and feed line lengths are calculated as F_W = 19.5mm with feed line width F_W = 2mm.

$$W = 1/2fr\sqrt{\mu 0\varepsilon 0} * \sqrt{(2/(\varepsilon r+1))} \qquad (1), [12]$$

W= antenna width

f_r= resonate frequency

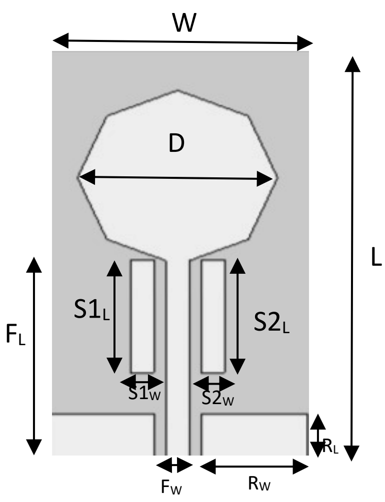
ε_r= permittivity

$$L = \frac{1}{2fr\sqrt{\varepsilon reff}\sqrt{\mu 0\varepsilon 0}} - 2\Delta L \qquad (2), [12]$$

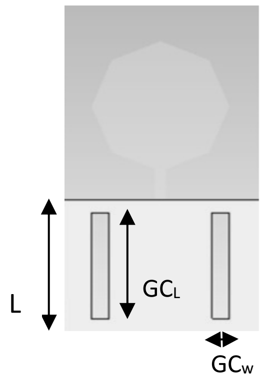
L= length of the antenna

△L= effective length of the antenna

εr_{eff}= effective permittivity



(a)



(b)

Figure 1: Novel Design (a) Octagon patch (b) Partial Ground

A DGS is taken on the bottom structure of the antenna substrate material in order to increase the S11 value. Slots in the ground with the dimensions GC_L = 13, GC_W = 2, and a height of h = 0.1 mm are depicted in *figure 1(b).* Four rectangular stubs with the measurements (11 x 2 x 0.1) mm are attached to the patch to boost bandwidth, as shown in *figure 1 (a*). The parameter values applied to the suggested antenna are displayed in *table* [15,16]

Table 1: Dimensions of Octagon design with partial ground

S. No.	Parameters	Value(mm)
1	W	23
2	L	40.5
3	D	17
4	F_L	19.5
5	F_W	1
6	$S1_L$, $S2_L$	11
7	$S1_W$, $S2_W$	2
8	R_W	9
9	R_L	5
10	G_{CL}	13
11	G_{CW}	2
12	L_1	16.5

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3. EVOLUTION OF OCTAGONAL SHAPED ANTENNA WITH DGS

Figure 2 displays the evolution stage of the proposed antenna. For the first step in the evolution process, we used full ground with dimensions of (40.5 x 23 x 0.1) and substrate dimensions of (40.5 x 23 x 0.7). The feed line length is 19.5mm and the width is 1.4mm. The octagonal patch's outer radius is 8mm, and antenna 1 is resonant at 9.792GHz with an S_{11} of -7.09, as shown in *figure 5*. The gain is observed to be 6.87dB for antenna1**.** For the second step of evolution, we used partial ground by implementing DGS [16]. The length of the ground was reduced to 16.57 and two rectangular slots were inserted into the ground with a length and width of 13 x 2mm, respectively, to increase the S_{11} value and bandwidth. *Figure 6* shows that antenna 2 resonates at 4.654GHz and 9.06GHz, with S_{11} values of 18.4 and 9.93, respectively. The gain is observed at 3.56dB and the wide band of 2.93GHz. In the third step in evolution, we inserted two rectangular stubs on the patch with dimensions of length and width of 11 and 5 respectively. The antenna3 then resonates at 4.584 GHz and 9.376 GHz, with S_{11} values of 19.69 and -9.88, as shown in *figure 7*. The gain is detected at 3.41dB and the wide band of 2.98GHz. By inserting the stubs, we increased overall performance. In the fourth step in the evolution, we inserted two rectangular stubs on the path, which increases the gain and decreases the value of $S_{11}$and the change in the radius of the octagonal patch to 8.55mm, which is used to achieve the ultra-wideband. By increasing the width of the feed line to 2mm, we got multi-bands. The Antenna 4 resonates at 3.25GHz, 5GHz, and 9.23GHz with an S_{11} of-27.5,-35.100, and -31.52, respectively. The gain is observed at 2.51dB, 3.67dB, and 2.02dB, respectively, and we achieve a UWB of 8.457GHz in *figure 8*. In the suggested antenna design, DGS is used. Adjusting the size of the slots in the patch and ground allows for easy tweaking of the operational frequency. To obtain the UWB frequency, the suggested antenna used an octagonal-shaped patch. The octagonal-shaped patch antenna's resonant frequency is determined by the length of the ground, whereas UWB is determined by the radius of the octagonal-shaped patch. By using felt as the substrate for this antenna, this has a permittivity of 1.22 and a tangent value of 0.016.

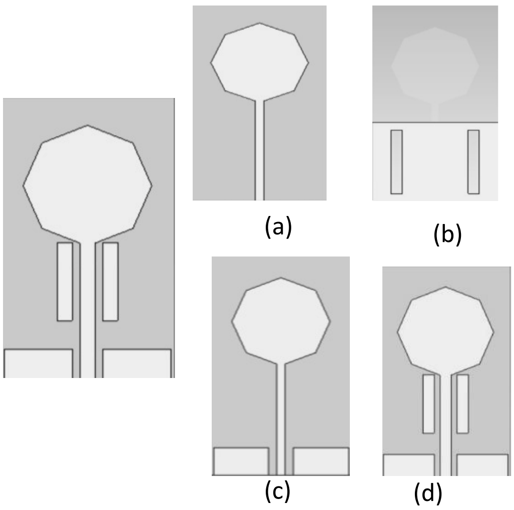

Figure 2: Evolution Stages of Octagon design

By loading a partial ground plane at the feeding point, additional reactance is introduced, which results in a wideband response. The role played by partial ground planes and special ground planes with slots is crucial to obtaining UWB performance [17]. A partial ground reduces the amount of energy stored in a substrate. As energy storage in the substrate's declines, the Quality factor decreases as well. A decrease in Q factor leads to an increase in bandwidth. Back radiation is the result of a partial ground plane. Therefore, more radiation loss. Therefore, the Q factor decreases, and bandwidth increases as a result.

$$Q = f_c / (f_2 - f_1) \quad (3), [12]$$

Q= Quality factor
f_c= Centre frequency
f_2= High frequency
f_1= Low frequency

In the ultra-wide band region, the non-periodic slots in round plane help the antenna to resonate widely due to its placement shown in *figure 2*. The application of DGS in microstrip antennas has increased bandwidth and gain while reducing higher mode harmonics, mutual coupling between neighboring elements, and cross-polarization, all of which have enhanced the radiation properties of the micro strip. [18].

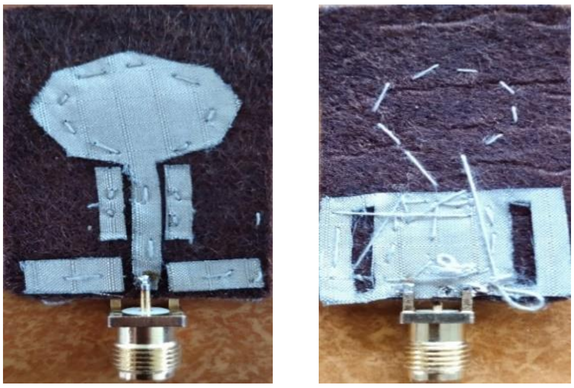

Figure 3: Fabricated Antenna Model

The fabrication of octagon radiator is shown in *figure 3* clearly indicates that dimensions are very small in size. The antenna is fabricated with a simple technique called as sewing and SMA connector is attached by soldiering at the edge of the feed line without any deformation of the antenna.

4. DEPERFORMATION PROCESS

The antenna's flexibility is determined using bending analysis [3, 22]. *Figure 11* depicts the performance of the proposed antenna when bent at various radius (R = 20, 30, 40, 50, 60) mm. The antenna resonates at 3.06 at a bend of 20R (radius =R) and the UWB remains constant. The antenna resonates at 3.112, 3.101, 3.112, and 3.112 GHz at 30R, 40R, 50R, and 60R bends, respectively. The antenna response is nearly identical at various bending radiuses, with minimal variance. As a result, the antenna's performance is unaffected by the deformation process [19-21].

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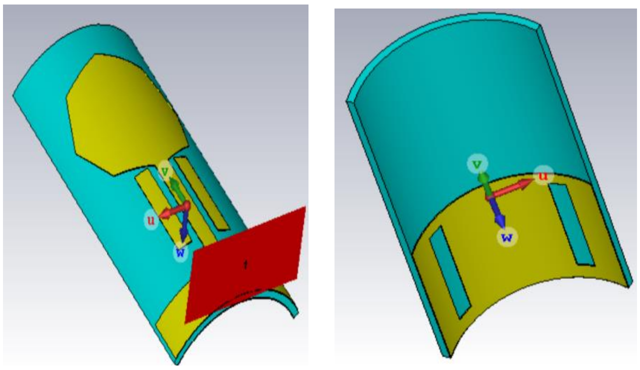


Figure 4: Bending analysis of X- axis

5. RESULT ANALYSIS

The result analysis gives the complete picture about the octagon design which helps to understand the characteristics of parameters i.e., bandwidth, reflection coefficient, gain and radiation pattern.

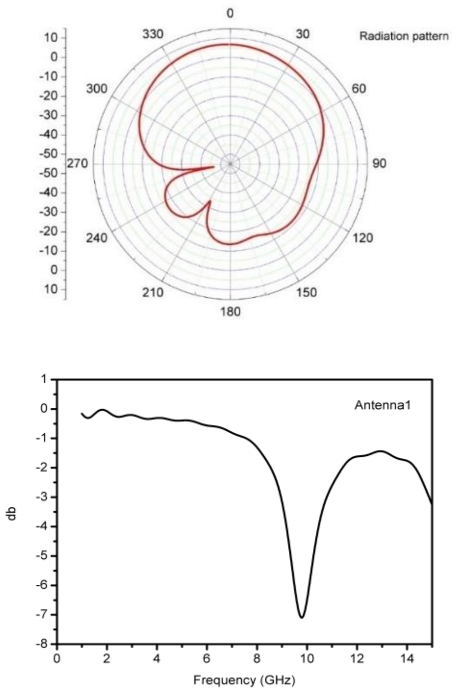
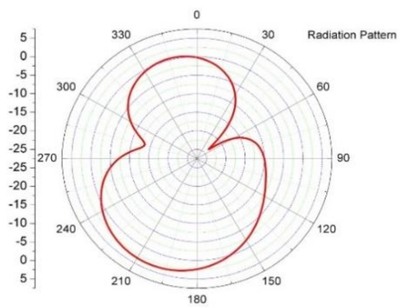


Figure 5: Antenna 1 radiation pattern & S11

The antenna 1 is full ground and simple octagon shape radiating patch which shows a result of S_{11} in *figure 5* around -7 dB not below the threshold -10dB not meeting the circumstance.



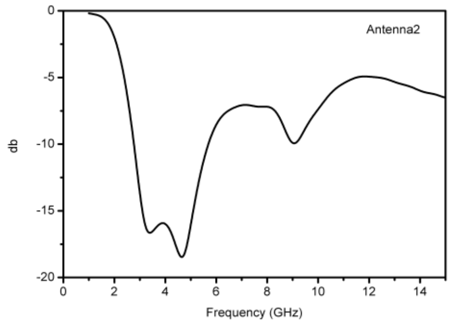


Figure 6: Antenna 2 radiation pattern & S_{11}

The ground with partial extraction as 13x2 mm2 as a periodic vertical slot makes the S11 cross the threshold value resonating at 4.8 GHz with less bandwidth by modifying antenna 2, shown in *figure 6*.

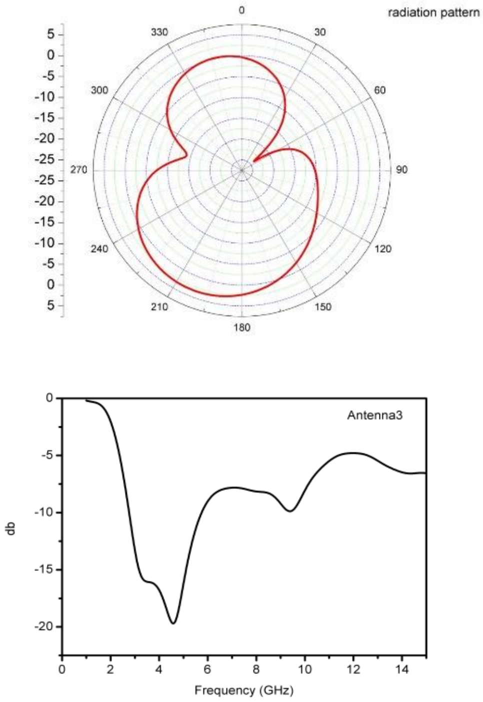
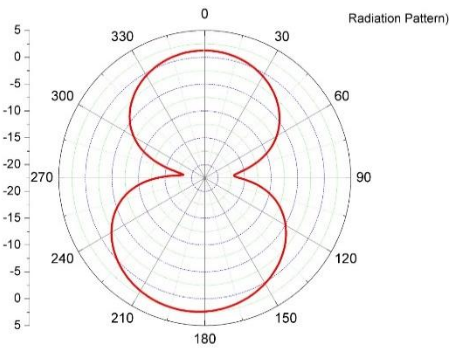


Figure 7: Antenna 3 radiation pattern & S_{11}

Using small coplanar wave structures on the front of antenna 3, S_{11} can be achieved at 4.8GHz, but with less bandwidth and a smaller radiation field shown in *figure 7*.



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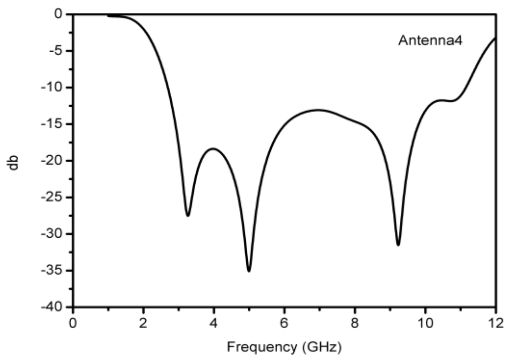

Figure 8: Antenna 4 radiation pattern & S_{11}

By placing multi-stubs on each side of the feed line, the antenna 4 maintains a S11 below -10dB threshold at 5 GHz with a -35.1dB end fire pattern shown in *figure 8*.

Figure 9: S_{11} with Network Analyzer

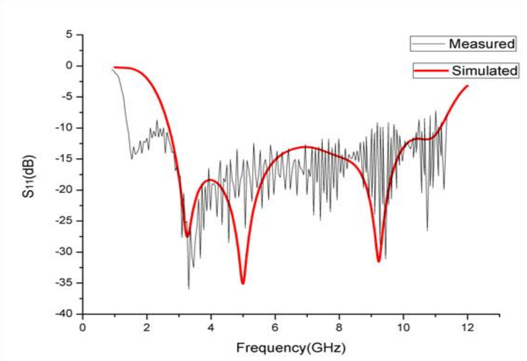

Figure 10: Measured and Simulation reflection coefficient comparison

Table 2: Result analysis of proposed antenna stages

Design	Operating frequency (GHz)	Gain(dBi)	S_{11} (dB)	Bandwidth (GHz)
Antenna 1	9.792GHz	6.87	-7.09	-
Antenna 2	4.654GHz	3.56	-18.4	2.93
Antenna3	4.585GHz	3.41	-19.69	2.98GHz
Antenna 4	3.1GHz	2.38	-27.5	8.475GHz
	5GHz	3.67	-35.1	(UWB)

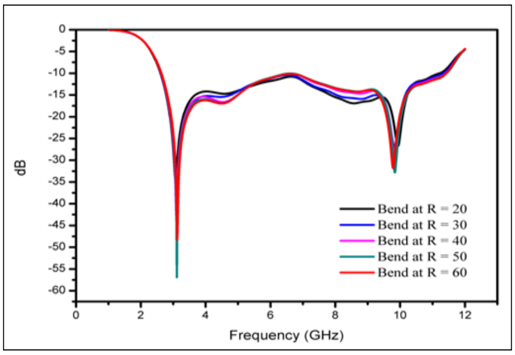

Figure 11: Bending analysis of antenna 4 with different radii in mm

Table 3: Result analysis of proposed antenna stages

Year, Ref.	BW-GHz	Antenna Dimensions (mm)	Substrate Material	S_{11} (dB)	Operating Frequency (GHz)	Applied DGS
2022, [1]	7	13 x 13	Polyamide	-58	7-14	No
2020,[19]	8.2	30 x 30	Felt	-10	3.1-11.3	No
2018,[22]	7.5	20 x 25	FR4	-55	3.1-10.6	No
2021,[23]	7.8	45 x 34	FR4	-27	2.9-10.7	Yes
Proposed Work	8.5	40 x 23	Felt	-35	2.6 – 11.1	Yes

6. CONCLUSION

The proposed design, is a polygon-shaped felt textile antenna with partial ground is constructed with the existing technology known as a periodic DGS, which enhances the gain and ultra-band accomplishes the multiband at 3.1 and 5GHz. It is employed for biomedical applications as well as commercial uses at 5GHz, attaining gain 3.67dBi at -35.1 dB reflection coefficient with wide band from 2.6 – 11.1 GHz and fully flexible substrate material satisfying bending conditions at various radius (R = 20, 30, 40, 50, 60) mm, which is unwavering throughout the antenna's frequency band for on body and in free space. The octagon designs is appropriate for WBAN applications, based on the deformation process.

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