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# A SIMPLE LOW-COST COMPACT FLEXIBLE ANTENNA FOR WEARABLE APPLICATIONS

[1]Ayman M. Qashlan, [2]Khalid H. Alharbi

[1]Student, [2]Assistant Professor

[1] Department of Electrical and Computer Engineering,

[1] King Abdulaziz University, Jeddah, Saudi Arabia

***Abstract:*** In this paper, a simple low-cost single-layer flexible monopole antenna is designed and proposed. The antenna consists of a radiation rectangle with staircase edges, Feeding line, and two ground planes with staircase shape. The antenna is designed on an inexpensive polyamide flexible material of thickness 0.1 mm and dielectric constant of 3.5. The proposed antenna has a compact size of 20×20×0.1 mm3. All antenna dimensions were varied and investigated to determine the best possible results, mainly, reflection coefficient and bandwidth. The design of the proposed antenna is carried out using the commercially available High Frequency Field Solver software (HFSS).

***Index Terms*** **– Flexible antenna, Monopole Antenna, Wearable Electronics.**

## I. Introduction

Over the past few years, the demand for wearable communication technologies has rapidly increased for application such as Internet of things (IOT), consumers electronics, and smart home application. Antennas plays a vital role in the rapid development of wearable electronics [1]. In 2002, the federal Communication Commission (FCC) allocated the frequency range of 3.1 – 10.6 GHz to Ultra-wideband (UWB) antennas. Since then, numerous numbers of UWB antennas were designed including rigid and flexible antenna. In wearable devices, flexible antennas are highly required for their unique features: small size, light weight, and flexibility [2-3].

Several flexible antennas were reported in the literature including Fractal-Slot Multiband Antenna [4], Dual-Band Flexible CPW-fed Antenna [5], Fan-Shaped and Trapezoidal Elements [6], and Miniaturized Cross-Lines Rectangular Ring-Shaped Flexible antenna [7].

In this paper, A simple low-cost single-layer compact flexible monopole antenna is designed and proposed. The antenna has a radiating rectangular shape with staircase edges fed through a 50 Ω microstrip line. It also has two identical rectangular ground planes with staircase edges coupled to the microstrip feedline. The antenna has a small size of 20 × 20 × 0.1 mm3 and is designed on inexpensive polyamide substrate of thickness 0.1 mm, relative permittivity 3.5, and loss tangent, tanδ = 0.02. The design of this antenna is carried out using the commercially available High Frequency Field Solver software (HFSS).

## II. ANTENNA DESIGN

The design of the antenna started with a simple radiating rectangle, microstrip feedline, and two Ground (GND) planes on each side of the microstrip line as shown in Figure 1. The width of the Microstrip line is 1 mm which result in a 50 Ω feedline characteristic impedance.

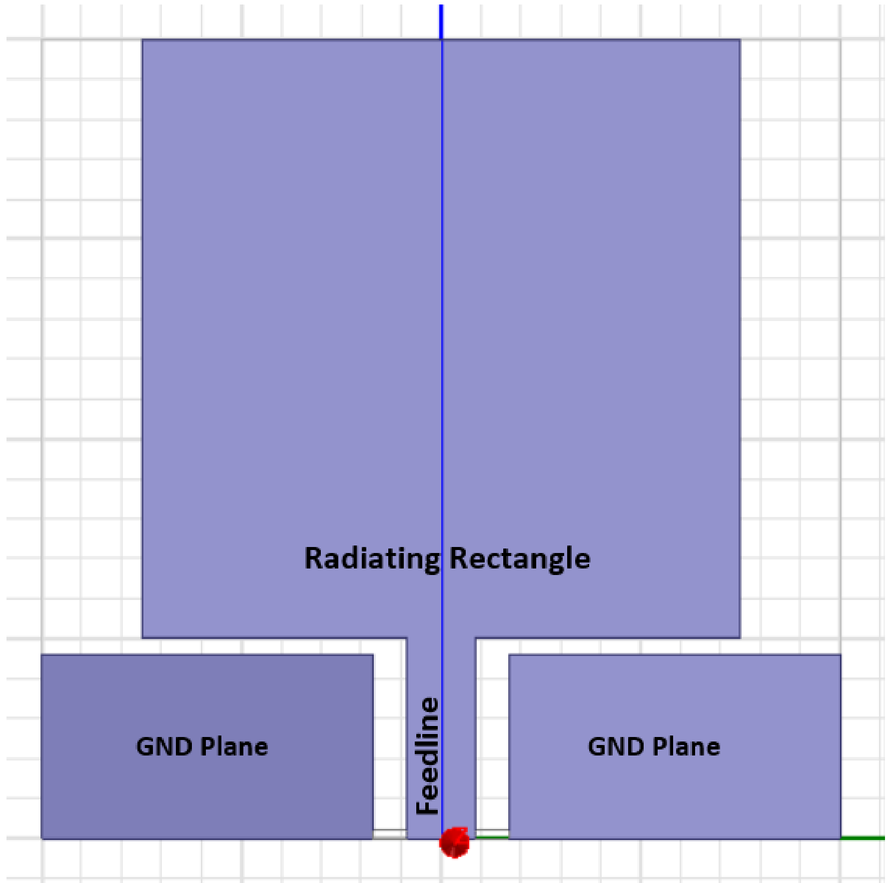



Figure 1 Basic Antenna Shape

Simulating the basic antenna shape showed a small resonant frequency at 5.8 GHz as shown in Figure 2. The antenna result is not sufficient for wearable applications because the bandwidth is very small, and the reflection coefficient is relatively high (-11 dB) at the centre frequency.

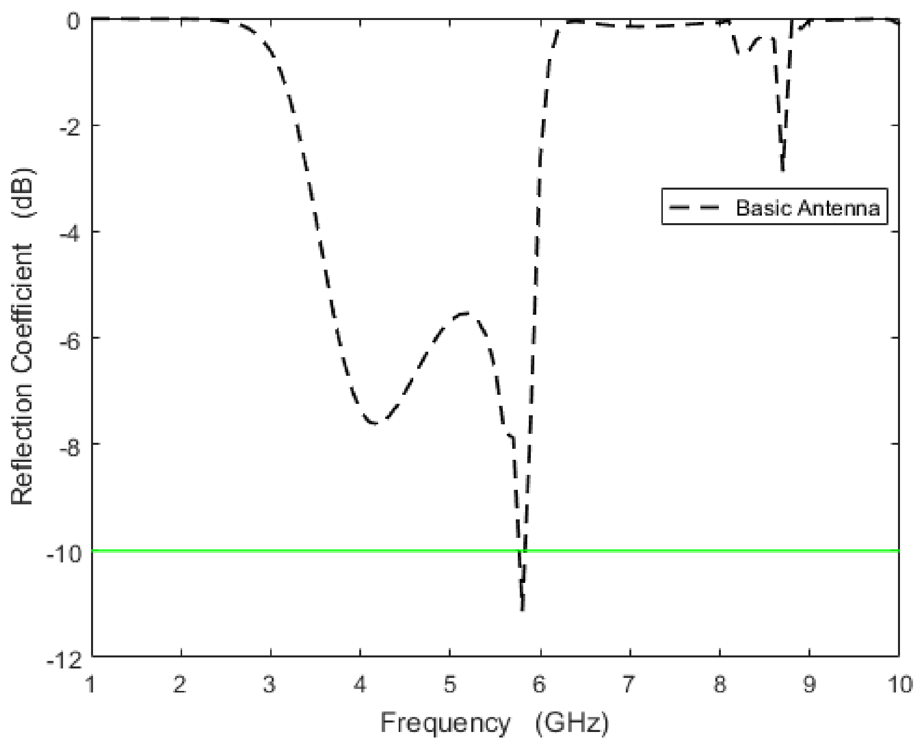
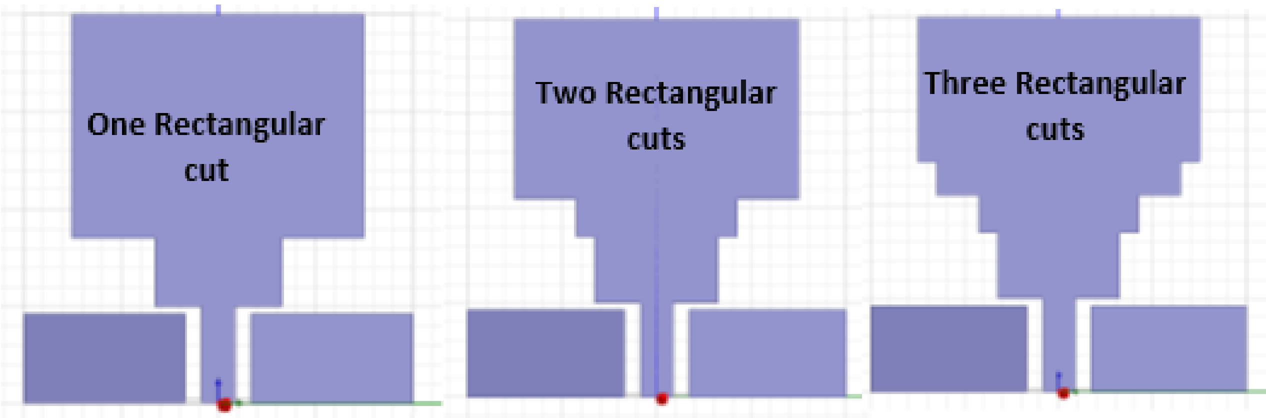



Figure 2 Reflection Coefficient of Basic Antenna

To increase the bandwidth of the antenna and enhance the reflection coefficient, rectangular cuts are added to the propagator shape of the antenna as illustrated in Figure 3. In Figure 3a, 3b, and 3c one, two, and three rectangular cuts added. The effects on antenna bandwidth and reflection coefficient are shown in Figure 4.




(a) (b) (c)

Figure 3 Rectangular Cuts added to Propagator a) One cut. b) Two cuts. c) Three cuts

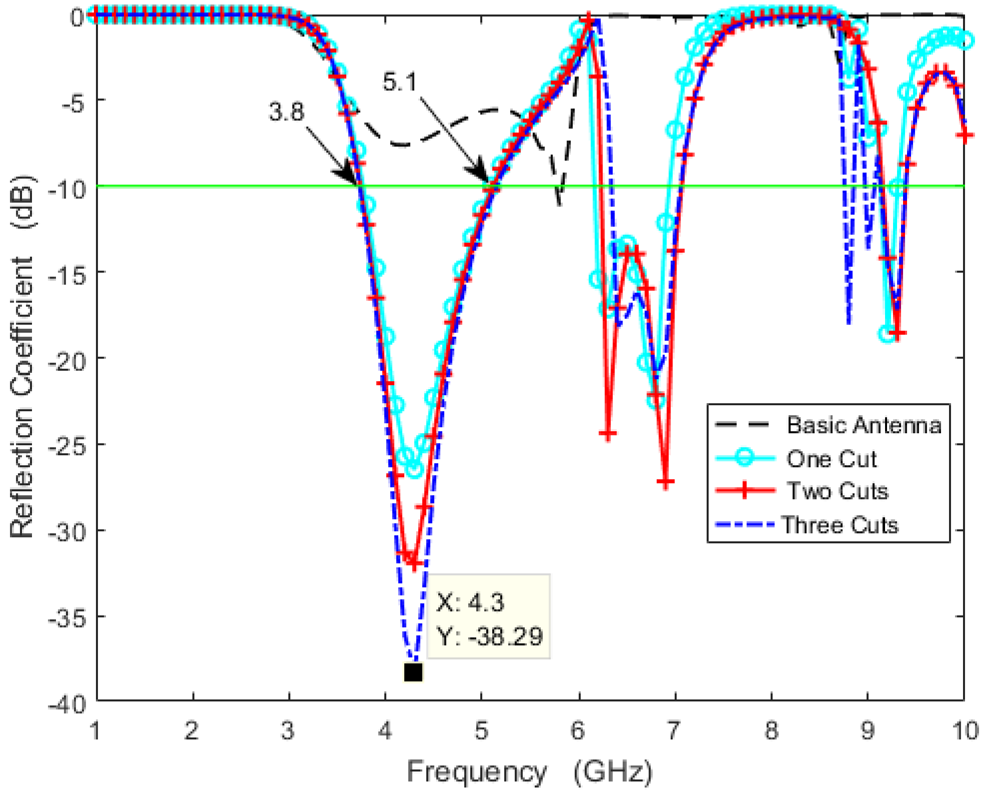
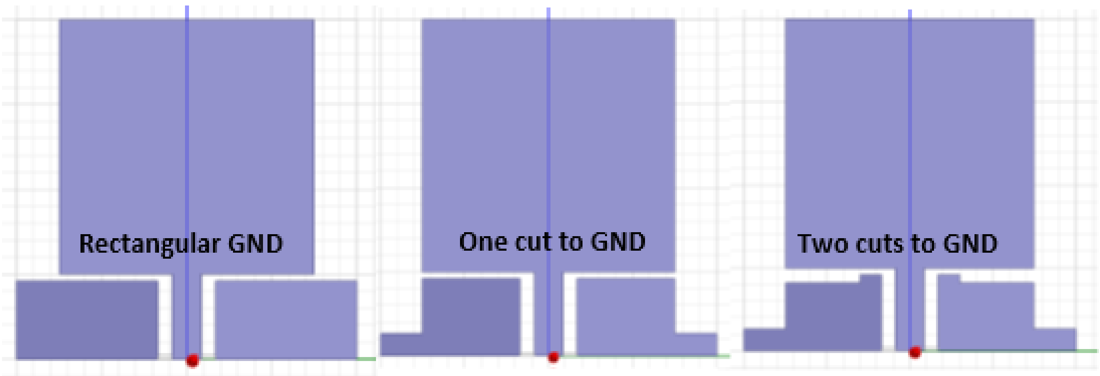



Figure 4 Effects of adding Rectangular Cuts to Propagator

As illustrated in Figure 4 adding rectangular cuts (stairs) to propagator shape enhances the bandwidth of the antenna and reflection coefficient. It also introduces a second and third resonant frequencies at 7GHz and 9 GHz, respectively. The best result is achieved when adding three cuts to propagator rectangle. The rectangular cuts can also be added to the GND planes as shown in Figure 5. The effects of adding the one and two cuts to GND plane are shown in Figure 6.




(a) (b) (c)

Figure 5 Rectangular Cuts added to GND Plane a) Basic Antenna. b) One cut. c) Two cuts

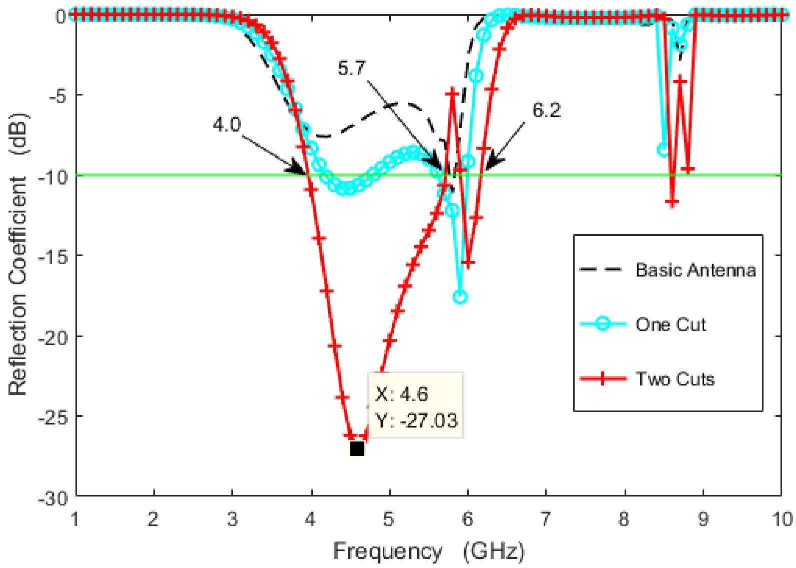



Figure 6 Effect of adding Rectangular Cuts to GND Planes

As seen in Figure 6 adding GND cuts (staired GND) enhances the bandwidth and reflection coefficient of the antenna. In the next step the staired propagator (with three cuts) is added to the staired GND plane with two cuts. The reflection coefficient of the staired propagator and staired GND planes is shown in Figure 7 in comparison to the staired propagator with rectangular GND and the rectangular propagator with staired GND.

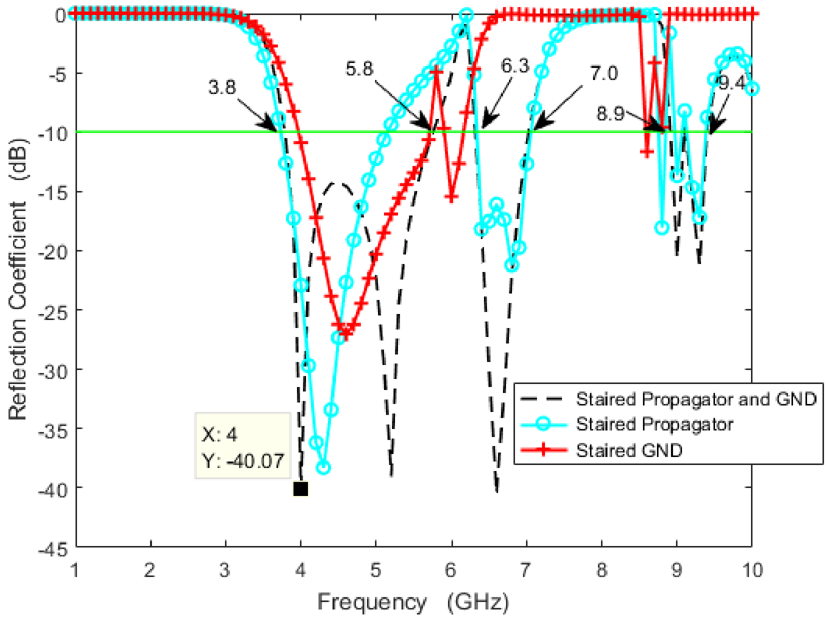



Figure 7 Comparison of Staired Propagator and GND planes

As explained on Figure 7, the staired propagator and GND planes antenna has the highest bandwidth and best reflection coefficient values. The antenna has three resonant frequencies at 4.0 GHz, 5.2 GHz, and 9.3 GHz with a bandwidth of 2GHz, 0.7 GHz, and 0.5 GHz, respectively. Thus, the antenna is suitable for wearable applications. The optimised antenna with staired propagator and GND plane is shown Figure 8 and the optimised antenna parameters are listed in Table 1.

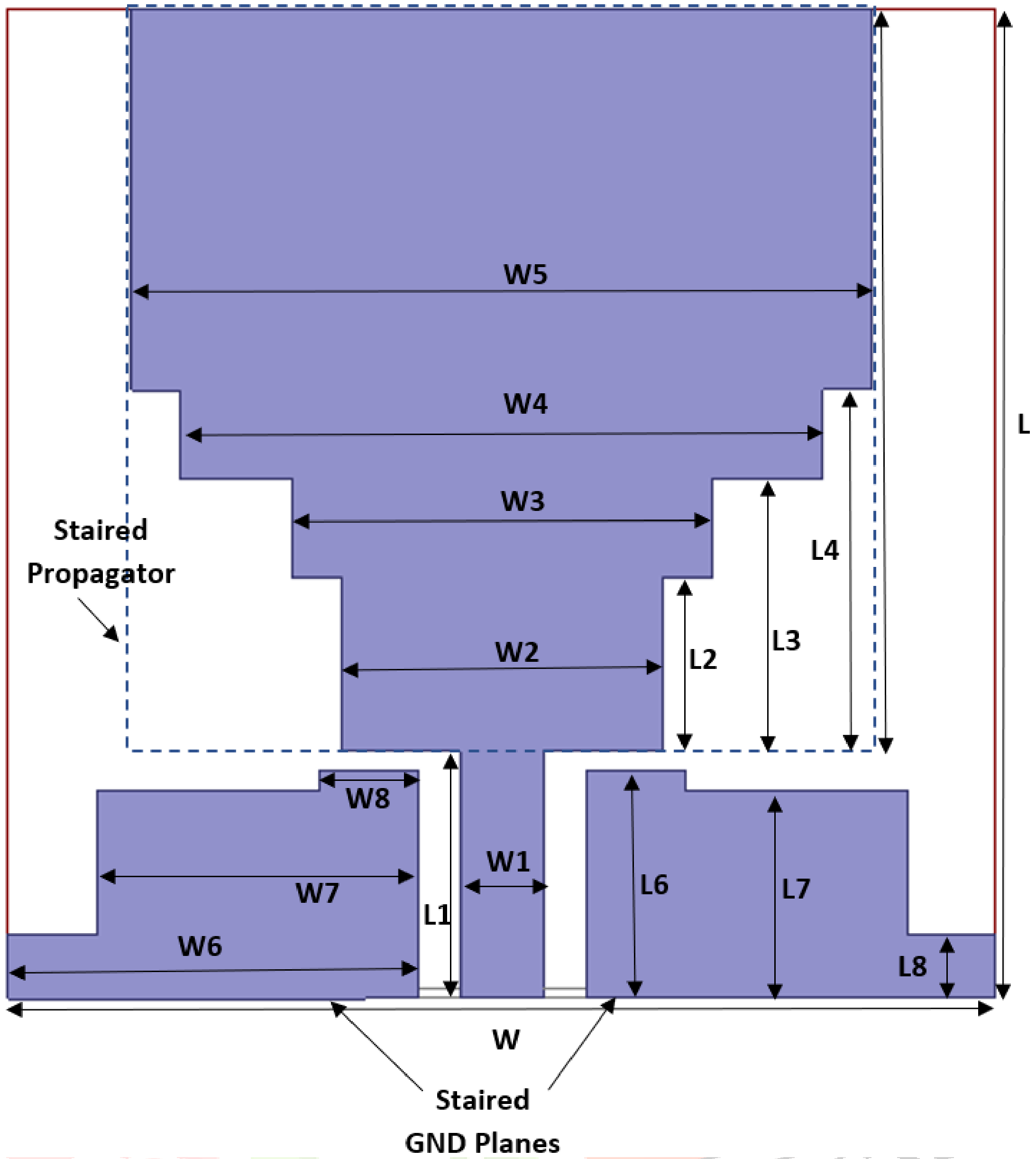



Figure 8 Optimized Antenna Parameters

Table I Optimized Antenna Parameters

| Parameter | Value (mm) | Parameter | Value (mm) |
|---|---|---|---|
| W | 20 | L | 20 |
| W1 | 1 | L1 | 5 |
| W2 | 6.3 | L2 | 3.3 |
| W3 | 8.3 | L3 | 5.3 |
| W4 | 13 | L4 | 7 |
| W5 | 15 | L5 | 15 |
| W6 | 8.3 | L6 | 4.6 |
| W7 | 5.7 | L7 | 4 |
| W8 | 1.2 | L8 | 1.2 |

The dimensions of the proposed antenna were optimised using trial and error approach. All proposed dimensions were varied and compared to yield the best possible result, mainly, highest bandwidth and best reflection coefficient. Figure 9a-9g show the effects of varying the w parameters listed in Table 1. the effects of varying the L parameters are shown in Figure 10a-10g. The parameters listed in table 1 yield the best possible result as seen Figures 9 and 10.

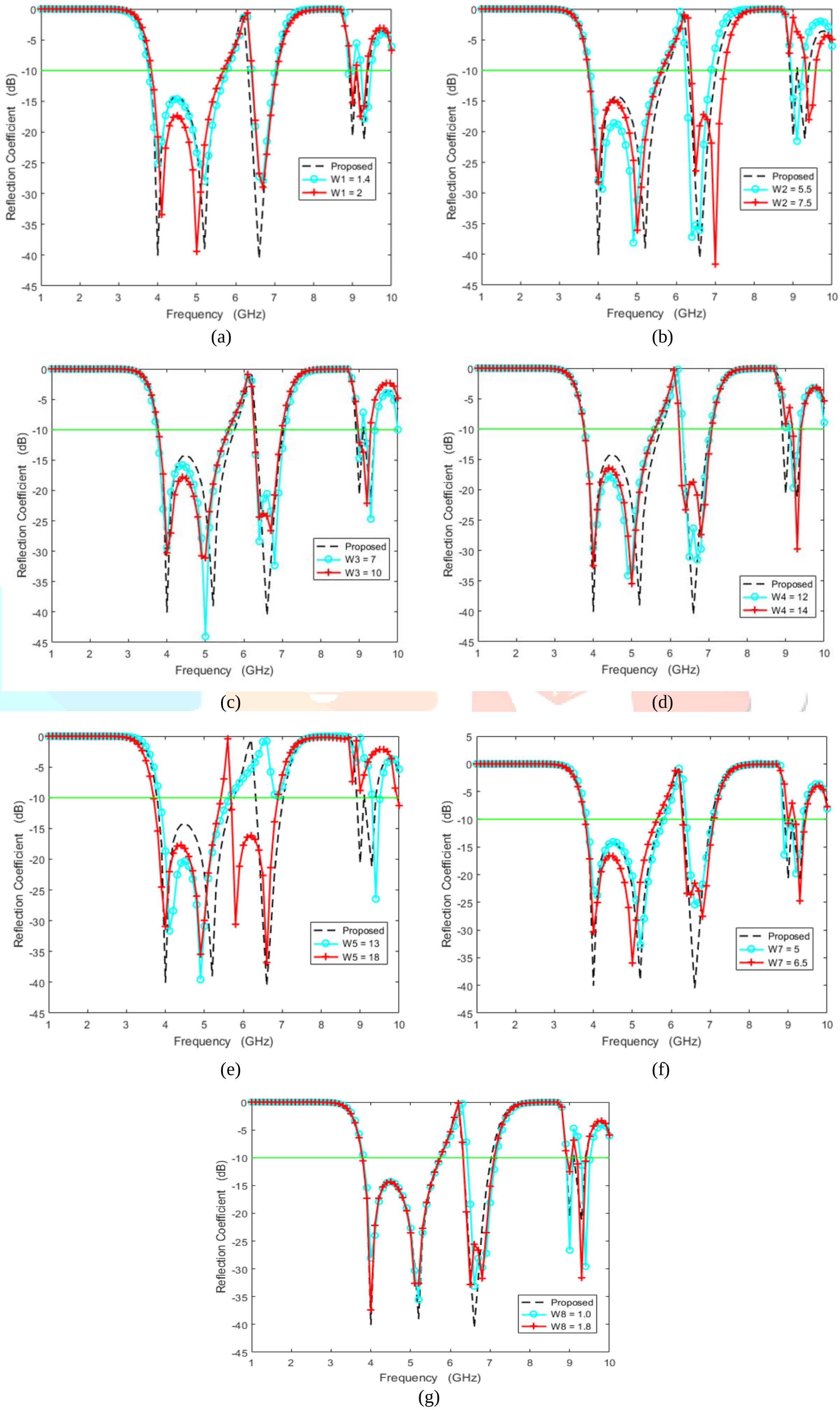
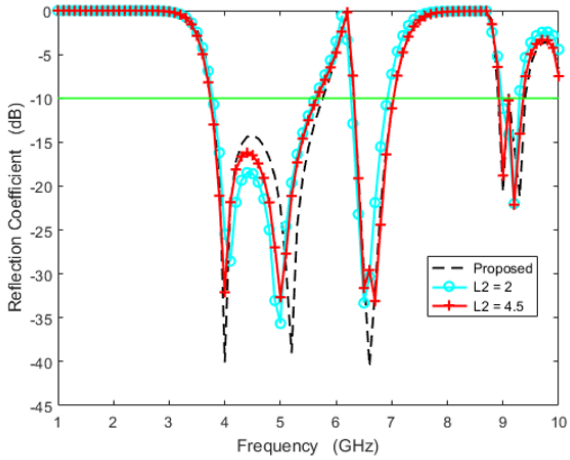
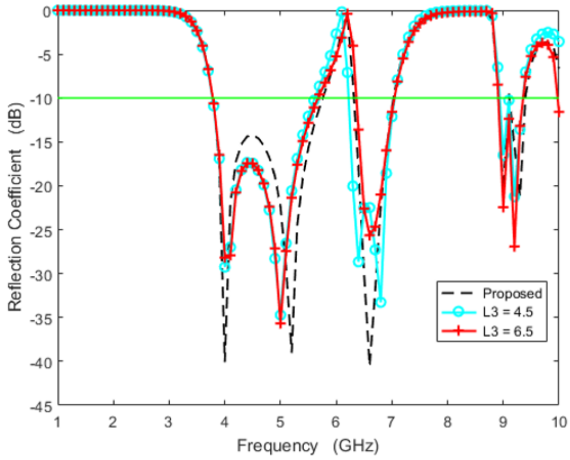


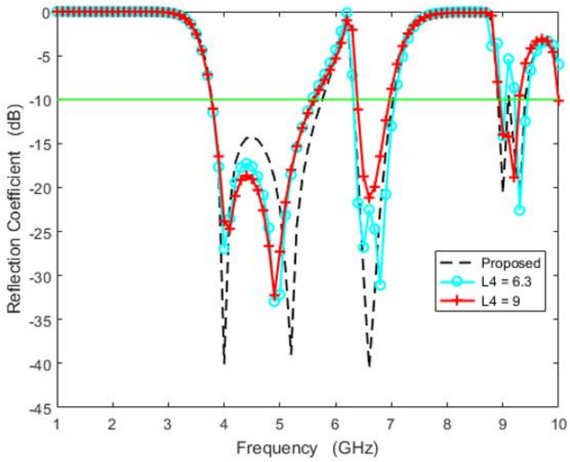

Figure 9 Effects of Varying W parameters. a) W1. b) W2. c) W3. d) W4. e) W5. f) W7. g) W8


Reflection Coefficient (dB)
Frequency (GHz)
Proposed
L2 = 2
L2 = 4.5

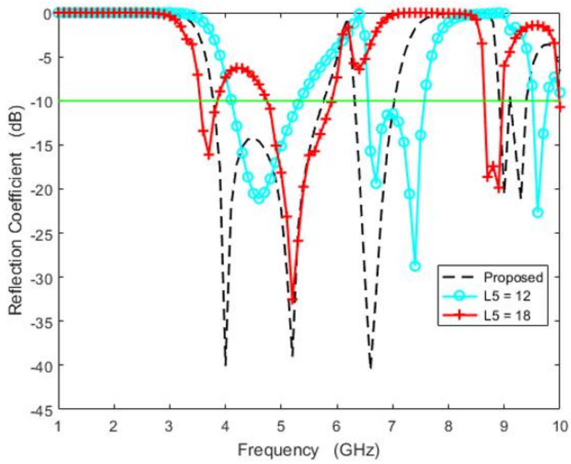
(a)


Reflection Coefficient (dB)
Frequency (GHz)
Proposed
L3 = 4.5
L3 = 6.5

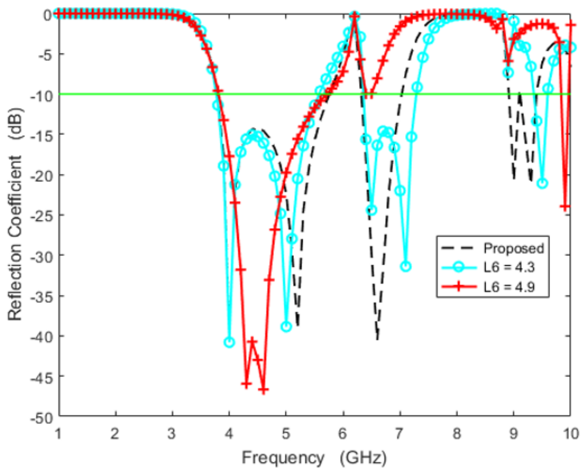
(b)


Reflection Coefficient (dB)
Frequency (GHz)
Proposed
L4 = 6.3
L4 = 9

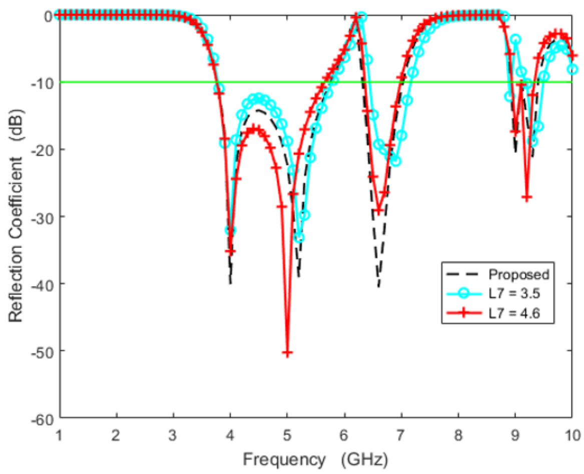
(c)


Reflection Coefficient (dB)
Frequency (GHz)
Proposed
L5 = 12
L5 = 18

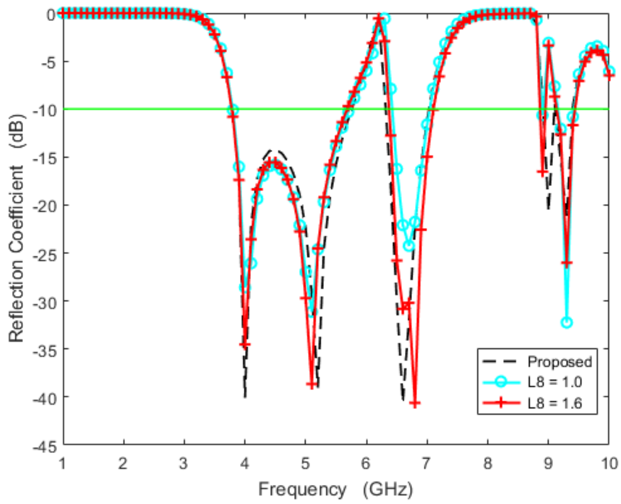
(d)


Reflection Coefficient (dB)
Frequency (GHz)
Proposed
L6 = 4.3
L6 = 4.9

(e)


Reflection Coefficient (dB)
Frequency (GHz)
Proposed
L7 = 3.5
L7 = 4.6

(f)




(g)

Figure 10 Effects of Varying the L parameters. a) L2. b) L3. c) L4. d) L5. e) L6. f) L7. g) L8

**III. RESULTS AND DISCUSSION**

The final optimised (proposed) antenna has three resonant frequencies centred at 4.0 GHz, 6.6 GHz, and 9.3 GHz. The impedance bandwidth for each resonant is 2 GHz, 0.7 GHz, and 0.5 GHz, respectively. The reflection coefficient of the antenna is shown in Figure 11. The antenna has an omni-direction radiation pattern as shown in Figure 12 and 13. The 3-d radiation pattern of the antenna is shown in Figures 12a, b, and c at 4.2, 5.3, and 6 GHz, respectively. Figures 13a, b, and c show the 2-d radiation pattern of the antenna at 4.2, 5.3, and 6.0 GHz, respectively where the XZ plane represent the E-field and the YZ plane represent the H-field. The maximum gain of the proposed antenna is 1.5 dBi at 4GHz, 2.0 at 6.6 GHz, and 2.8 GHz at 9.3 GHz. The maximum gain is shown from 1-10 in Figure 14.

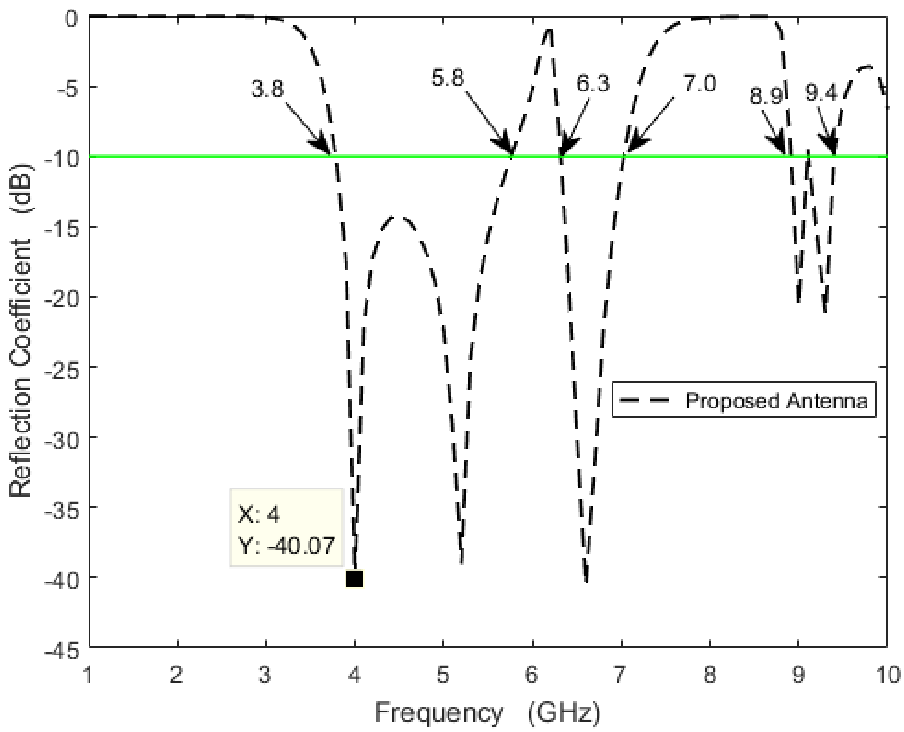



Figure 11 Reflection Coefficient of Proposed Antenna

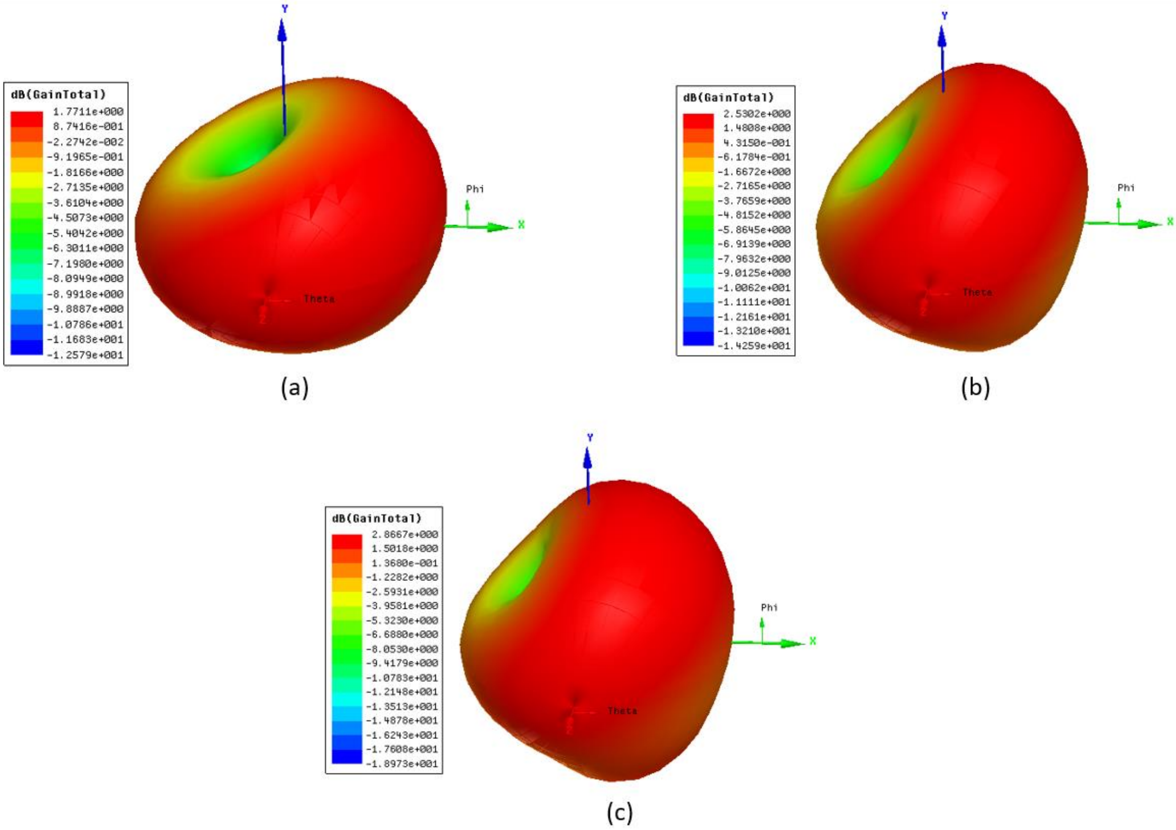
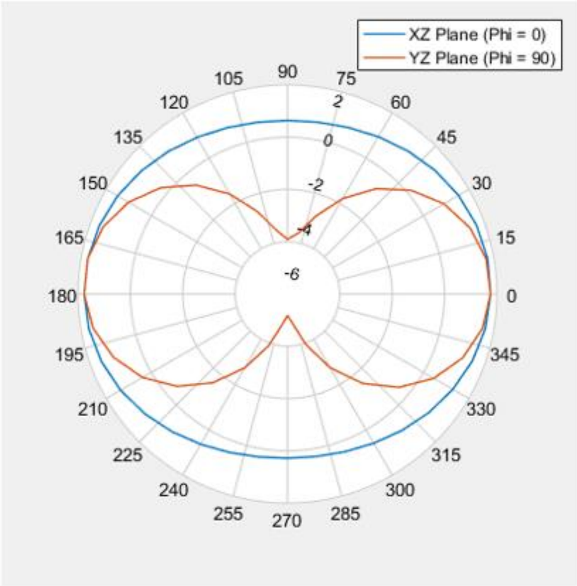
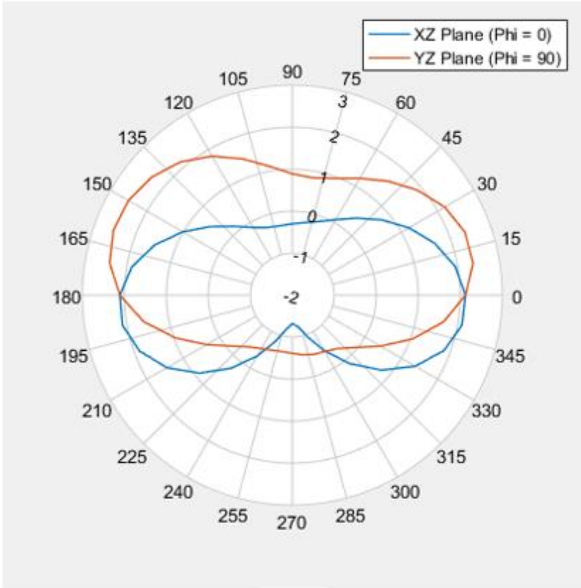


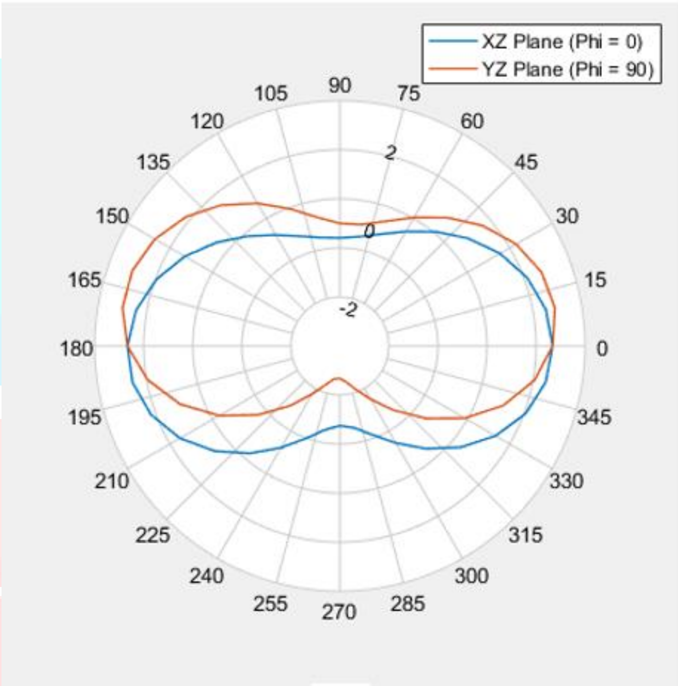

Figure 12 3-d Radiation Pattern at a) 4.2 GHz. b) 5.3 GHz. c) 6.0 GHz.




(a)




(b)




(c)

Figure 13 2-d Radiation Pattern at a) 4.2 GHz. b) 5.3 GHz. c) 6.0 GHz

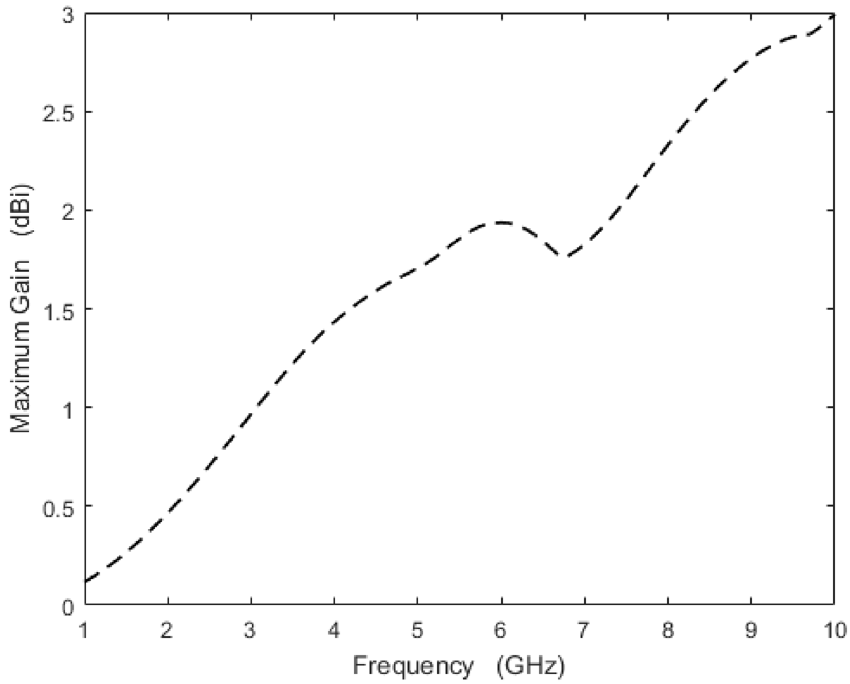



Figure 14 Maximum Gain of Proposed Antenna

## REFERENCES

**[1]** Ullah, M., Islam, M., Alam, T., and Ashraf, F. 2018. Paper-based flexible antenna for wearable telemedicine applications at 2.4 GHz ISM band. Sensors, 18(12), 4214. Doi:10.3390/s18124214

**[2]** Haraty, M. R., Naser-Moghadasi, M., Lotfi-Neyestanak, A. A., and Nikfarjam, A. 2016. Transparent Flexible Antenna for UWB Applications. ACES JOURNAL, 31(12), 1426–1430.

**[3]** Zahran, S. R., Gaafar, A., and Abdalla, M. A. 2016. A flexible UWB low profile antenna for wearable applications. 2016 IEEE International Symposium on Antennas and Propagation (APSURSI). Doi:10.1109/aps.2016.7696672

**[4]** Ahmed, S., Tahir, F. A., and Cheema, H. M. A Flexible Low Cost Fractal-Slot Multiband Antenna for Wireless Applications. School of Electrical Engineering and Computer Science, National University of Sciences and Technology.

**[5]** Atrash, M. E., Bassem, K., Abdalla, M. A. 2017. A compact dual-band flexible CPW-fed antenna for wearable applications. 2017 IEEE International Symposium on Antennas and Propagation. Doi:10.1109/apusncursinrsm.2017.8073274

**[6]** Hiraguri, K., Koshiji, F., and Koshiji, K. 2014. A flexible broadband antenna with fan-shaped and trapezoidal elements formed on printed circuit board for ultra-wideband Radio. 2014 International Conference on Electronics Packaging (ICEP). Doi:10.1109/icep.2014.6826794

**[7]** Javed, A., Ejaz, A., Mehak, S., Amin, Y., Loo, J., and Tenhunen, H. 2019. Miniaturized Cross-Lines Rectangular Ring-Shaped Flexible Multiband Antenna. ACES JOURNAL, 34(5), 625–630.