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Enhanced Ultra Wide Band E Shaped Patch Defective Ground Plane Microstrip Antenna for Wireless Communication Applications

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ABSTRACT

This paper presents the enhanced UWB E-shaped defective ground microstrip antenna for wireless communication applications. In this antenna by using partial ground plane, single step corner truncated E-slot patch enhances the allocated UWB bandwidth range 3.1-10 GHz to 1.81-13.08 GHz. The effects of feed gap between patch and ground plane with respect to feed line for enhancing the bandwidth is also proposed in this study. The antenna gives highest bandwidth of 151.64% for g= 2mm. The proposed antenna is designed and simulated using Ansoft HFSS13. A prototype of the antenna is fabricated and measured successfully. A good agreement between simulated and measured results is obtained. The antenna can be used for most commonly used narrow band systems PCS, WiMAX (3.4 GHz-3.69 GHz), IEEE 802.11a, wireless local area network (5.15 GHz-5.35 GHz, 5.725 GHz - 5.825 GHz), HIPERLAN/2 (5.450 5.725 GHz), 7.7 GHz-8.5 GHz for lower X-band, for satellite communications S-DMB, WiBro, CMMB etc. In the measured impedance bandwidth from 1.8-13.08 GHz, for VSWR < 2 the gain of the antenna varies from 1.6 dB to 5 dB on its operating band.

Keywords - E-shaped patch, UWB, Wireless communications, Defective ground plane.

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I. INTRODUCTION

For UWB system an antenna design and implementation is a challenging issue. The main concern in UWB antenna design and development is to achieve extremely wider bandwidth with suitable and optimal size. In 2002, the US FCC allocated an unlicensed UWB band range is from 3.1 to 10.6 GHz [1]. However up to 7.5GHz of bandwidth is required for a workable UWB antenna. The UWB technology can also be employed for indoor wireless communication such as in portable devices; the size of the UWB antennas must be sufficiently small so that they can be easily integrated into various devices, and in radar/medical imaging and target sensor data collection. Omnidirectional radiation pattern property, uniform gain, high radiation efficiency of the designed UWB antenna is very useful in communication between transmitters and receivers. The UWB frequencies specifications are shown in Fig. 1. Recently, number of UWB antennas have been designed and proposed for 3.1-10.6 GHz applications [2-8]. Such as dome-shaped antenna [2], diamond shape antennas [3-4], ring antenna [5], wide slots antennas [6-8], triangular patch antennas [9], monopole antenna with defective ground plane [10-18].

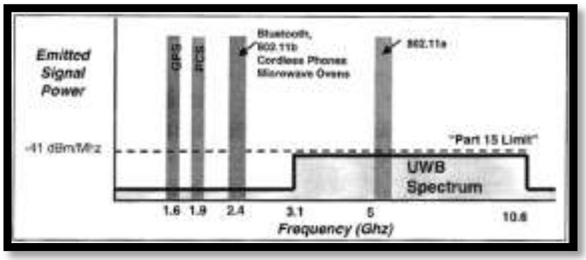


Fig.1 UWB frequency specifications

This paper focuses on the design and development of enhanced UWB bandwidth planar printed circuit board (PCB) antenna capable to operate even more frequency range shown in Fig.1. Simple investigations are carried out for the development of UWB antennas from the past to present. First simple monopole rectangular microstrip antenna with partial ground plane is designed at 3GHz and analyzed. Next the attempts are made out for the best slot types for the UWB characteristics. From the results of this study an enhanced UWB monopole single step E-shaped patch microstrip antenna with defective ground plane is proposed in terms of impedance bandwidth, radiation pattern, current distribution, and gain. The effect of feed gap between E-shaped patch and ground plane with respect to feed line on bandwidth is also proposed in this study.

II. THE PROPOSED UWB ANTENNA GEOMETRY

The optimized geometry of the single stepped E-shaped patch UWB microstrip antenna (SSESPUWBMSA) is shown in Fig.2. The antenna is placed in the X-Y plane and the normal direction is *Z*-axis which defines the thickness of the substrate. As shown in Fig. 2, L and W are the length and width of the rectangular patch fed by a 50 Ω microstripline feed of length L_f and width $W_{f.}$ placed at the centre of the geometry. Single step E-shaped patch is composed from two horizontal slots S1,S2 and one vertical slot S3 of dimensions L1×W1, L2×W2 and L3×W3 with symmetrical single-steps of length La and width Wa shown in Fig.2. The antenna is design and fabricated onto a piece of modified-epoxy substrate of dimensions 60×60 mm^2 shows the length Ls and width Ws of the substrate with dielectric constant of 4.2, thickness of 1.6 mm and loss tangent is 0.02. On the other side of the dielectric substrate, a ground plane with the width Ws and length Lg is printed below the microstrip feed line clearly shown as bottom ground plane in Fig.2.The antenna parameters with dimensional values are as shown in Table1.

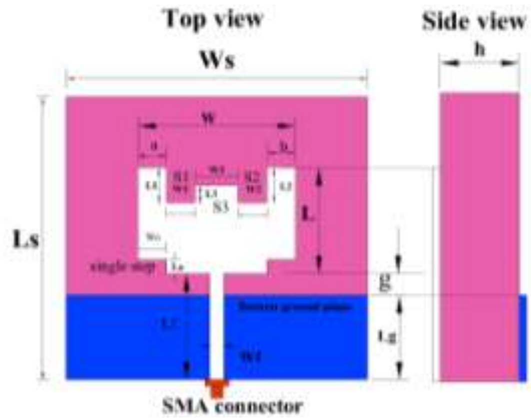
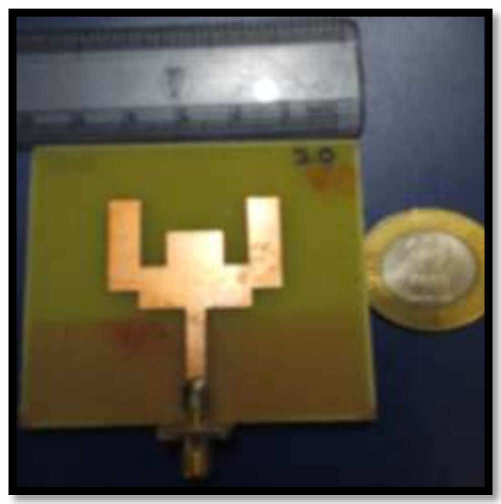


Fig.2 Geometry of proposed SSESPUWBMSA

Front and back view of the fabricated SSESPUWBMSA is shown in Fig.3. Proposed design of SSESPUWBMSA as shown in Fig.2 is fabricated using the photolithographic technique. In this method unwanted metal areas of the metallic layer are removed through the chemical etching process by which desired design is obtained. A sub miniature A (SMA) connector (brass metal) is connected to join the microstripline feed and ground plane of the fabricated antenna through this excitation to antenna is made. This connector offers low reflections and constant 50 ohm impedance. After fabrication process, all the parameters of proposed antenna are measured using vector network analyzer (VNA).



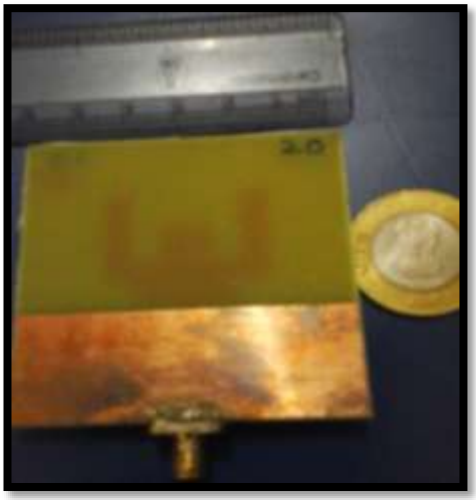


Fig.3 Front and back view of the fabricated prototype SSESPUWBMSA

Table 1. The optimized designed parameters of the proposed antenna

Parameters	Dimensions in mm
Substrate size Ls×Ws	60×60
Patch size L×W	24×31
Feed line Size $L_f \times W_f$	23.3×3.2
Single step size La×Wa	4×5.5
Slot S1 size L1	15×5
Slot S2 size L2×W2	15×5
Slot S3 size L3×W3	5×10
Ground size Ws× Lg	60×21.3
g	2
a and b	5.5

III. SIMULATED AND FABRICATED RESULTS AND DISCUSSIONS

For the proposed design as shown in Fig.2 the simulation is done using Ansoft simulation software high frequency structural simulator (HFSS) based on finite element method (FEM). The simulated and measured return loss versus frequency plot for the optimized SSESPUWBMSA is as shown in Fig.4. From this figure, it is clearly seen that a good agreement between the measured and simulated results is achieved. The antenna gives an impedance bandwidth of 151.61% which covers frequency range from 1.81 to 13 GHz. Therefore, the proposed SSESPUWBMSA can cover the Bluetooth, Worldwide Interoperability for Microwave Telecommunication System (UMTS), Wireless Local area Network (WLAN) and many ultra-wideband UWB systems used for wireless communication applications.

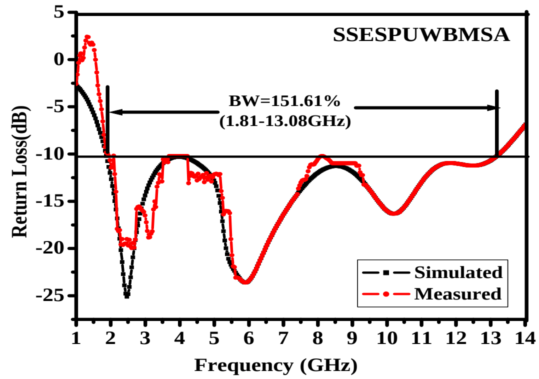


Fig.4 Measured and simulated return loss versus frequency plot of the proposed SSESPUWBMSA

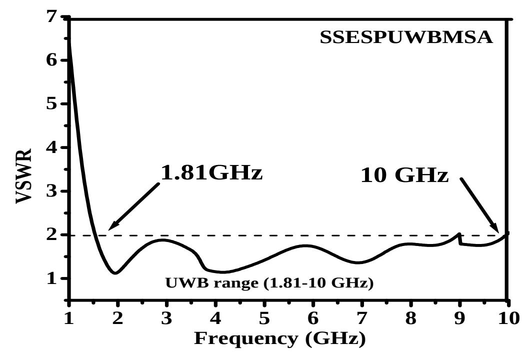


Fig.5 Simulated VSWR versus frequency plot of the proposed SSESPUWBMSA

Figure5 shows the variation of VSWR versus frequency of SSESPUWBMSA. From this figure it is seen that the VSWR<2 lies from 1.81-13.08 GHz validates the results shown in Fig.4.The antenna gives the peak gain of 5dB in its operating band.

The distance *g* between the E-shaped patch with respect to feed line length L_f and the partial ground plane dimension Lg have large effects on the bandwidth enhancement. The effect of g by keeping other parameters fixed of the proposed antenna have been studied and presented. Figure 6 shows the simulated return loss versus frequency curves for g=1, 2, 3, 4 and 5mm. It is seen from Fig.6 that, the operating bandwidth of the antenna varies remarkably with the variation of g. It is clearly shown in the figure that the bandwidth becomes wider when the ground plane dimension L_g is closer to the edge of patch that is for 'g' is equal to 2mm and 1mm the proposed antenna covers the frequency range from 1.81 to more than 13 GHz. This is because, due to highest coupling effect between patch and defective ground plane as they radiates independently close to each other resulting wider bandwidth. This optimum dimensions has been taken in fabricating the SSESPUWBMSA.

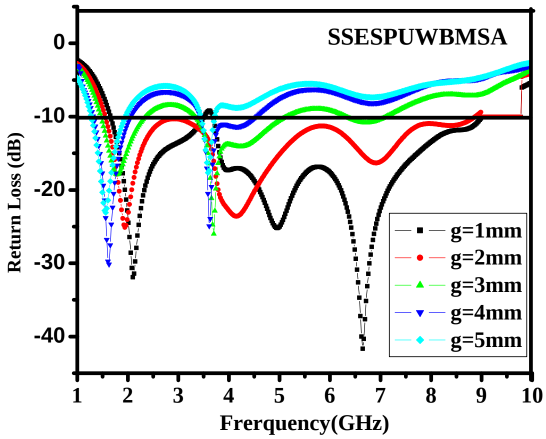
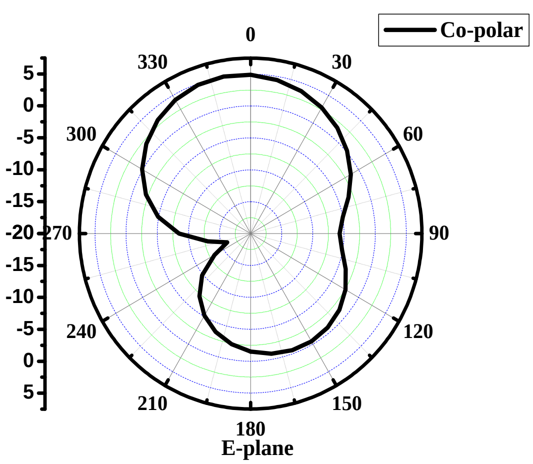
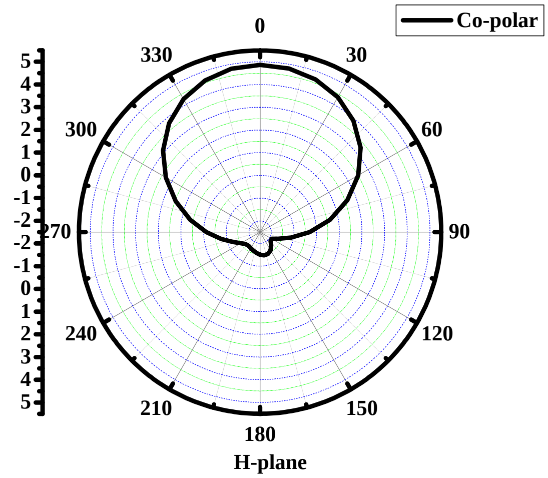


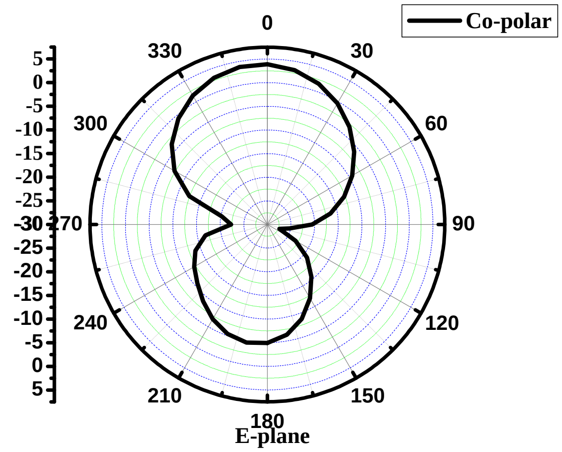
Fig.6 Simulated return loss versus frequency curves of SSESPUWBMSA for g=1, 2, 3, 4, and 5mm keeping L_g=21.3 mm and L_f=23.3mm constant

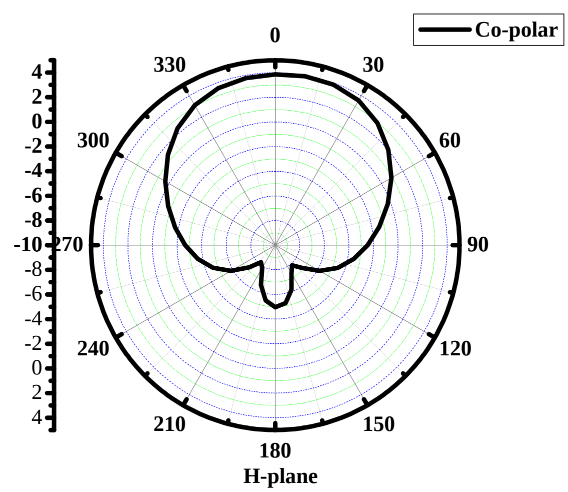
The typical co-polar far-field E- and H-plane radiation pattern SSESPUWBMSA measured at 1.96 GHz, 4.15GHz and 6.89 GHz are shown in Fig.7. From these figures it is seen that the patterns are nearly omnidirectional in nature.



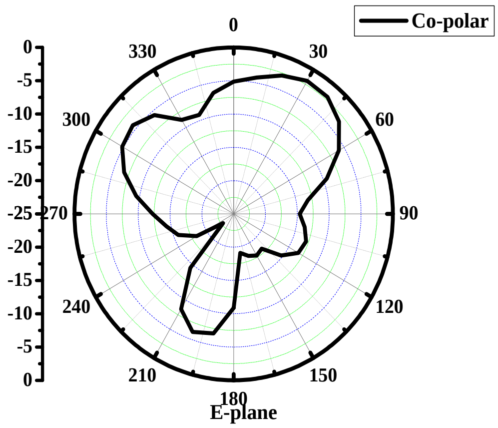


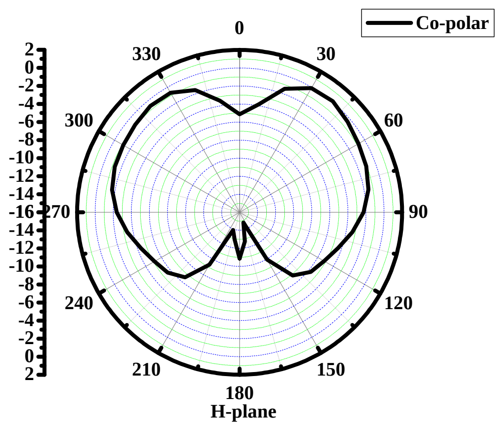
(a)





(b)

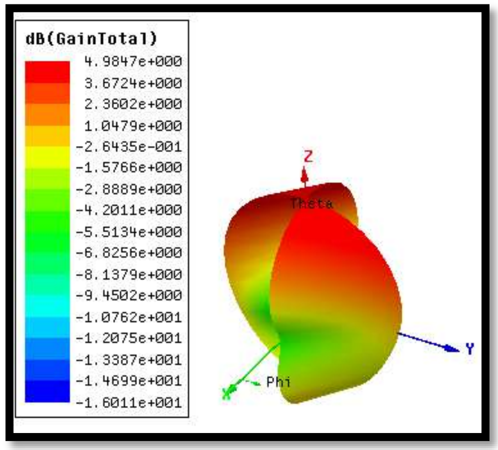


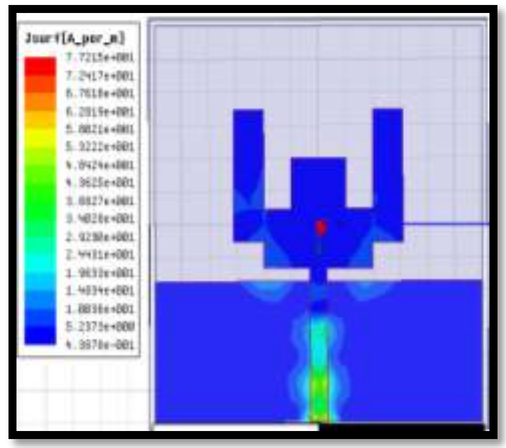


(c)

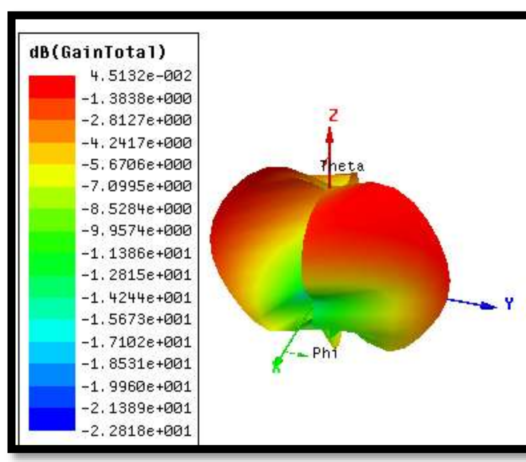
Fig.7 Typical radiation pattern of SSESPUWBMSA measured at (a) 1.96 GHz, (b) 4.15 GHz, and (c) 6.89 GHz

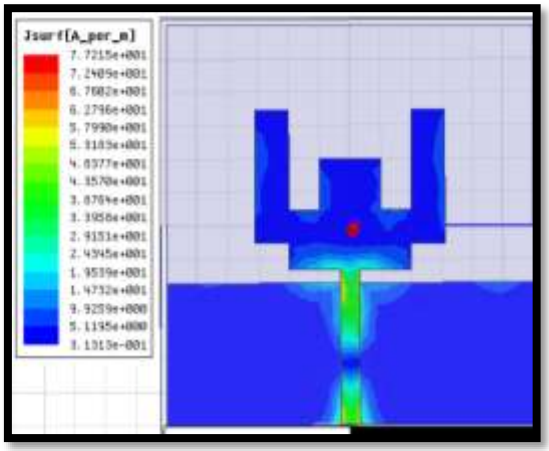
A typical simulated 3-dimensional far field radiation pattern and the current distribution of SSESPUWBMSA measured at 1.96, 4.15 and 6.89 GHz are shown in Fig.8. It is clearly seen in the figure that, current is mainly distributed along the microstripline feed and at the edge of the E-shaped patch which indicates that, the antenna is resonating well in its operating band.



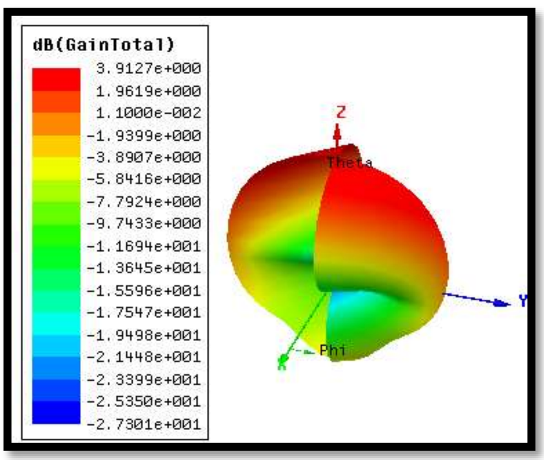


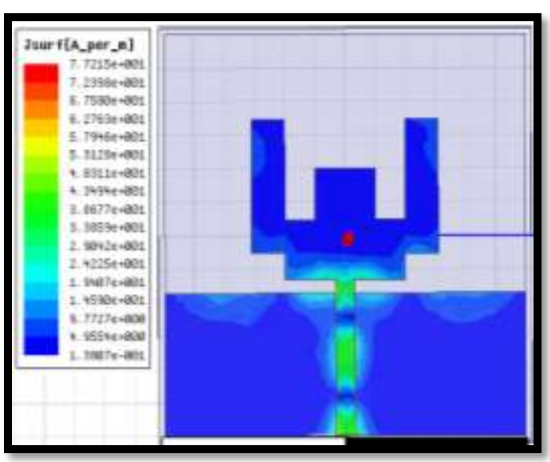
(a) 1.96 GHz





(b) 4.15 GHz





(c) 6.89 GHz

Fig.8 Simulated 3-d far field radiation pattern and current distribution of SSESPUWBMSA measured at (a) 1.96 GHz, (b) 4.15 GHz, and (c) 6.89 GHz.

Figure 9 shows variations of input impedance of SSESPUWBMSA in the frequency range of 1 - 10 GHz. It is seen from the Fig.9 that the input impedance varies between 26 to 38Ω. The positive values of impedances nearer to the characteristic impedance of 50Ω indicate better impedance matching and low loss in the device.

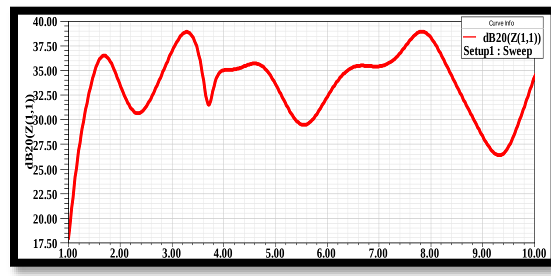


Fig.9 Variation of input impedance of SSESPUWBMSA

Group delay is another important characteristic which shows the performance of the antenna. The antenna should be able to transmit the electrical pulse with minimal distortion. The group delay of the proposed antenna over the operational bandwidth is shown in Fig.10.The variation is less than 0.5 ns over the frequency band from 1 to 10 GHz which shows that, the antenna has low-impulse distortion and is suitable for many UWB communication applications.

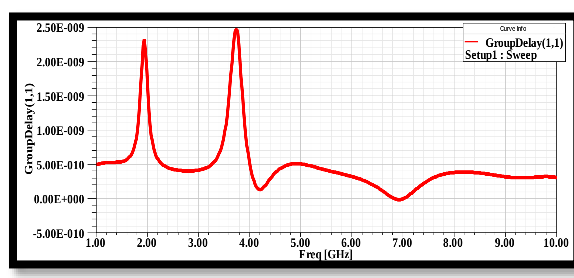


Fig.10 Simulated Group delay of SSESPUWBMSA

IV CONCLUSIONS

A novel design of enhanced UWB bandwidth E-shaped patch radiator microstrip antenna is proposed and a prototype is fabricated. The measured bandwidth of the antenna is from 1.81 GHz to 13 GHz. The antenna has been fabricated using low cost modified epoxy substrate material of volume of 23.3×24×1.6 mm^3. The measured results show a good agreement with the simulated results. The proposed antenna is suitable in most of the UWB systems applications. The antenna exhibits an almost omnidirectional radiation patterns in its operating band and gives a peak gain of 5 dB. Due to simplicity in its design complexity the antenna can be considered as a potential candidate for cost effective UWB wireless communication applications.

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