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Research Paper

A compact disc loaded curved elliptical shaped ultra-wideband MIMO antenna

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Abstract

The ultra wide band (UWB) Multiple-Input- Multiple-Output (MIMO) antenna with coplanar waveguide (CPW) having size of 18 x 23 x $0.8mm^3$ is designed for ultra-wideband (UWB) applications. The designed MIMO antenna contains two symmetrical circular disc loaded curved elliptical monopoles on top of the substrate and common ground plane with Y slot and extended T-shaped stub on bottom of substrate. The T- shape stub is placed on the ground plane to have the better antenna impedance matching and to enhance the isolation between the two antenna ports. To further improve the isolation in between the ports 1 and 2, and also on the ground plane a Y-shaped slot is fixed. Good impedance matching ($|S_{11}| < -10$dB) in the range from 2.8GHz to 12 GHz is provided by the proposed antenna, and an enhanced isolation of -27dB, low ECC of below 0.002, an acceptable gain of about 7 dBi and an efficiency of above 90%. The obtained result proves that the designed antenna is more appropriate for the portable devices.

Keywords: *Envelop Correlation Coefficient (ECC); Impedance Matching; Multiple Input Multiple Output (MIMO); Mutual Coupling; Ultra- Wideband.*

1. Introduction

Ultra-wideband (UWB) technology is the most useful technology for short distance communications in Wireless Body Area Networks (WBAN) and Wireless Personal Area Networks (WPAN) due to its attractive features like less cost, very high security, high information rate transmission, impulse like channel response and low power consumption. It transmits data at lower power levels by using the wider bandwidths. Ultra wideband technology gained more attention of researchers since the Federal Communications Commission (FCC) approved 3.1GHz to 10.6 GHz unlicensed frequency range with emission power level of <-41.3 dBm/MHz for UWB technology for commercial applications in 2002 [1]. However, ultra-wideband technology suffers from the multipath fading problem in indoor environments which limits distance of communication. MIMO technology provides the feasible solution for multipath fading problem by exploiting multipath to improve the range of communication without the need of extra power and spectrum. However, placing several antennas with compact size and less mutual coupling between them in a space limited portable devices is always a tedious task for antenna designers [2, 3]. Several decoupling structures for UWB MIMO antennas were proposed in the literature to provide low mutual coupling between antenna elements for wireless portal devices [4, 14]. The decoupling structures includes tree like structures [4], a cross shaped slot [5], protruded ground stubs [6, 8], a wide band neutralization [9], a metal reflector between the antenna elements [10], a T-shaped ground stub [11], couple of defected ground structures [12, 13], and T-shaped stub with Y slot structure [14]. A compact UWB MIMO antenna of size 18 x 23 x $0.8mm^3$ for portable devices applications is proposed in this paper. Two symmetrical disc loaded curved elliptical monopoles which are fed by coplanar waveguide feed are used as radiating elements of proposed UWB MIMO antenna. The common ground plane consists of protruded ground with Y shaped slot and an extended T-shaped stub. The proposed antenna has a good impedance matching in the between from 2.8 to 12 GHz frequency range. ($|S_{11}| < -10$dB), low mutual coupling ($|S_{21}| < -27$dB), stable peak gain and radiation efficiency covering the whole Ultra-wideband range[16-27]. The following sections describe the antenna design process, effect of T-shaped stub and Y slot.

2. Antenna Design

The ultra wide band (UWB) Multiple-Input- Multiple-Output (MIMO) antenna with coplanar waveguide (CPW) feed with the dimensions of L x W x h =18mm x 23mm x0.8mm is depicted in the Figure 1. The MIMO antenna is etched on the F4B-2 substrate material having 0.8mm thickness, the dielectric constant (ε_r) of 2.65, and the loss tangent 0.02. The proposed antenna contains two symmetrical disc loaded curved elliptical monopoles radiating antennas which are fed by coplanar waveguide by 50-Ω on top of the substrate as depicted in the Figure 1. A protruded ground with Y shaped slot and a T- shape stub is employed on the other side of substrate. To enhance the antenna impedance matching and to improve isolation (S_{21}) in between the antenna ports, the T- shape stub is deployed on to the common ground plane. To even more increase the isolation a Y-shape slot is used on the ground plane. The Table 1 shows the improved dimensions of the proposed antenna.

Table 1: Dimensions of the proposed antenna (in mm)

L	W	L1	L2	A
18mm	23mm	9.2mm	6.5mm	0.4mm
L3	L4	L5	L6	D
4.9mm	2.6mm	1.2mm	3mm	4mm
L7	L8	W1	W2	W3
1.6mm	6.9mm	2.4mm	10.3mm	7mm

3. Results And Discussions

The measures of the designed antenna are optimized and antenna is simulated using the Ansoft's HFSS v.13 software. The parameters of antenna like impedance matching, surface current distributions, mutual coupling, peak gain, radiation patterns, and radiation efficiency of the designed antenna are discussed in the sections. The Figure 2 and 3 illustrates the S-parameters at different stages of the proposed antenna. It can be viewed from the Figures 2 and 3, that without T shaped stub and Y slot on ground plane the ultra wideband MIMO antenna has lower resonant frequency at 6.2 GHz which is very larger than 3.1GHz and mutual coupling of about -12dB. With T stub and without Y slot on ground plane the antenna is resonating at 3 GHz which is below 3.1GHz and mutual coupling of lower than -25dB in between the elements of the antenna as observed from Figure 2 and 3. With the use of T shaped stub and Y slot (proposed antenna) very good impedance matching in the frequency range from 2.8 GHz to 12 GHz (S_{11} < -10dB), and a good isolation of less than -27dB is obtained as seen from the Figure 2 and 3. The T shaped stub acts as a reflector which diverts the currents on the antenna. Hence, the T shaped stub improves impedance matching over entire ultra wideband and also improves the isolation in between the ports. The isolation is further enhanced by inclusion of Y slot on the ground plane.

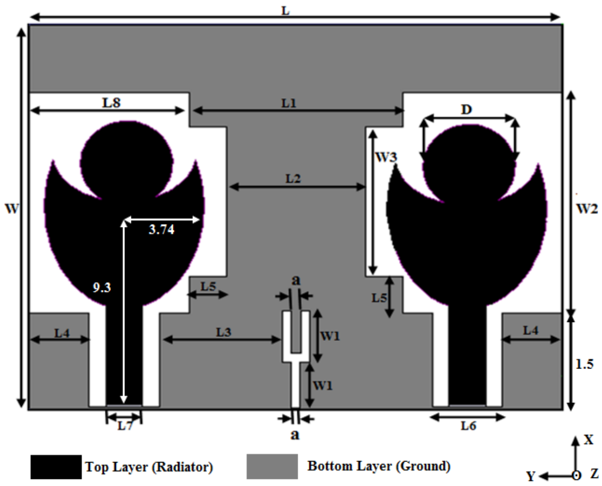

Fig. 1: Geometry of the proposed UWB MIMO antenna

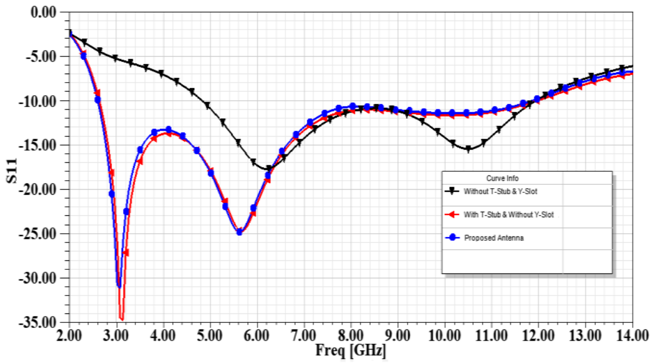

Fig. 2:S_{11} parameter of proposed antenna

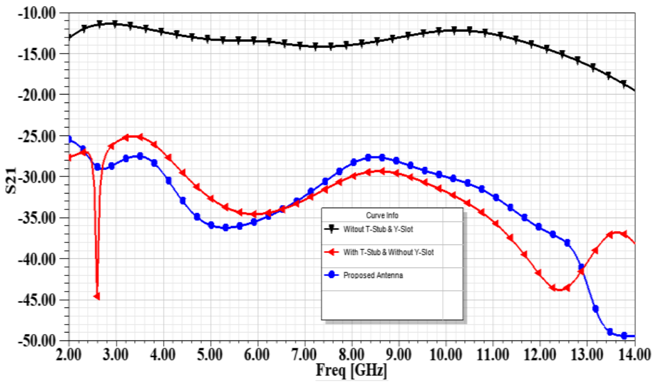

Fig. 3: S_{21} parameter of proposed antenna

The effect of T-shape stub and Y- shape slot on the performance of UWB MIMO antenna is clearly explained by surface current distributions at 10.6 GHz which is shown in the Figure 4 (a) - (c). It can be viewed from the Figures 4 (b) and 4 (c) that T shaped stub and Y slot efficiently blocking the surface currents entering from the ports 1 to 2.

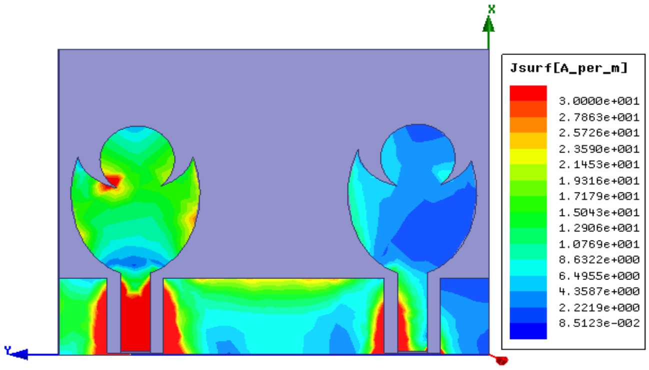

Fig. 4 (a): Without T stub and Y slot on ground.

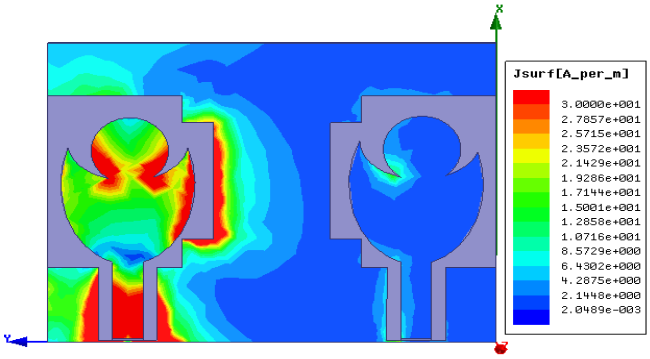

Fig. 4 (b): With T stub and without Y slot on ground.

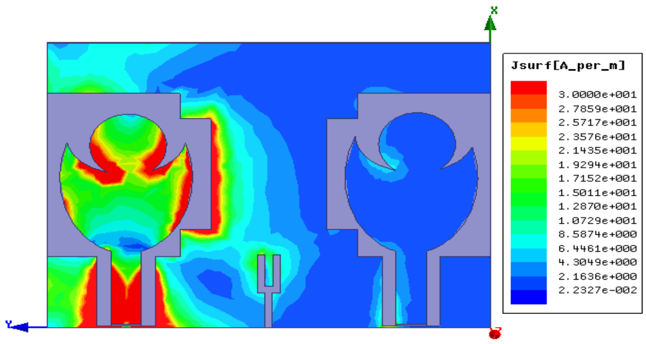

Fig. 4 (c): Proposed antenna.

Fig. 4: Effect of T stub and Y slot on UWB MIMO antenna.

The diversified performance of the designed antenna has been analyzed by using surface current distributions, 3-D radiation patterns, and envelope correlation coefficient (ECC). Figure 5 (a) - 5 (c) describes the surface current distributions when the port-1 is excited at frequencies of 3.1, 5.6, and 10.6 GHz respectively. It is clearly evident from the Figure 5 that huge current is radiated by the port 1 and very negligible amount of current is leaked into port 2. Similarly, from Figure 6 (a) - 6 (c), it is seen that most of the current is radiated from port 2 and considerably less current is entering into port 1. Hence, the proposed antenna giving good diversity performance in entire UWB ranges.

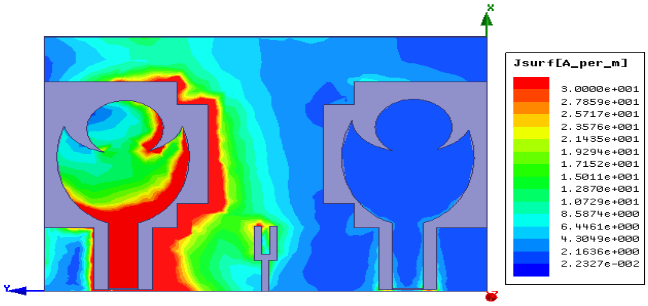

Fig. 5 (a): Current distribution at 3.1 GHz.

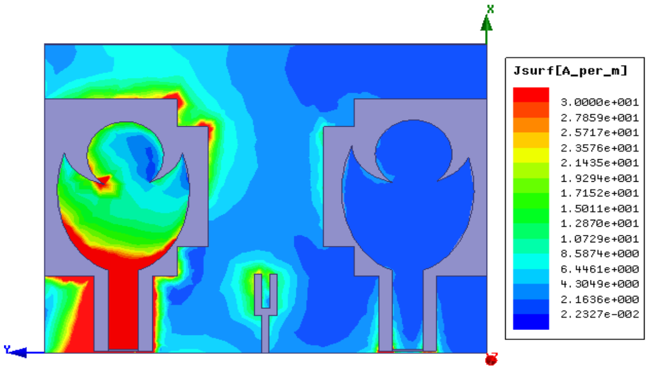

Fig. 5 (b): Current distribution at 5.6 GHz.

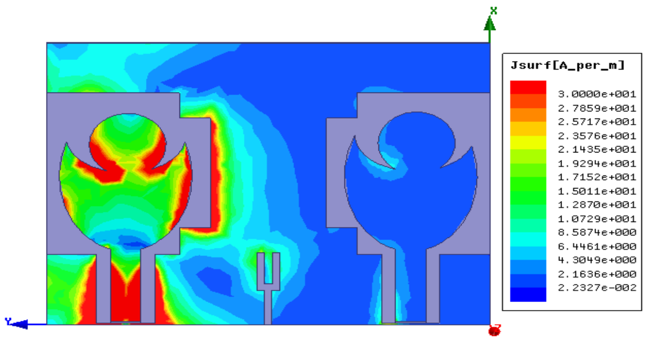

Fig. 5(c): Current distribution at 10.6 GHz.

Fig. 5: Current distributions when the port 1 is excited.

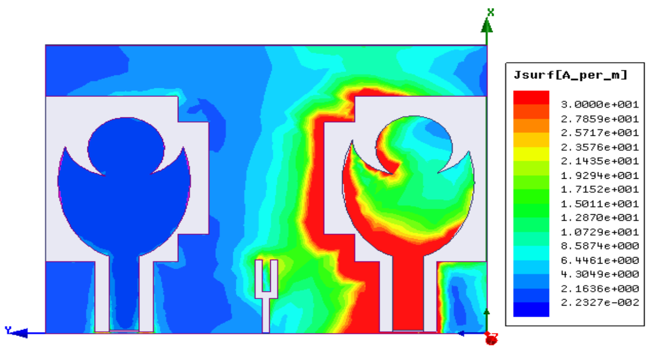

Fig. 6 (a): Current distribution at 3.1 GHz.

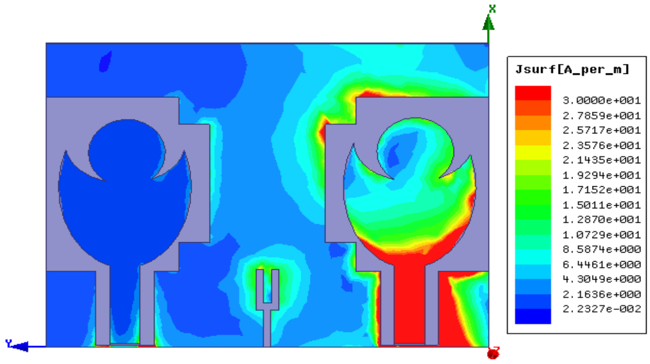

Fig. 6 (b): Current distribution at 5.6 GHz.

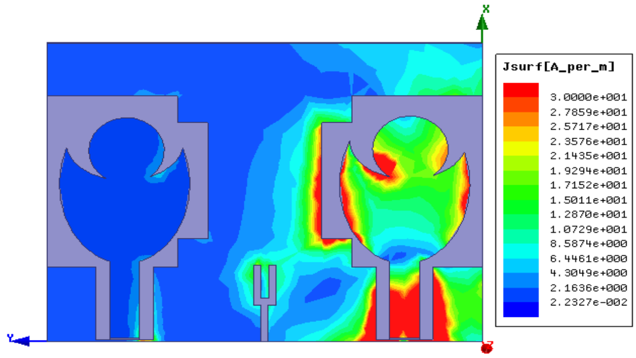

Fig. 6 (c): Current distribution at 10.6 GHz.

Fig. 6: Current distribution when port 1 excited.

The 3-D polar plots shown in Figure 7 and 8 illustrates the proposed antenna pattern diversity when the port-1 is excited and the port-2 is ended with load of 50Ω and vice-versa at 3.1GHz, 5.6 GHz, and 10.6 GHz, respectively. It is observed from the Figures 7 and 8 that the patterns are diverted by some angles, hence good pattern diversity is achieved.

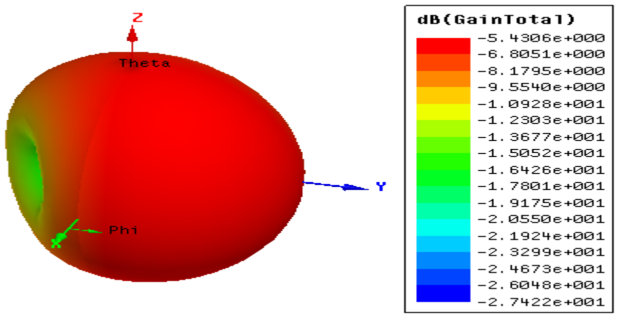

Fig. 7 (a): 3-D polar plot at 3.1 GHz.

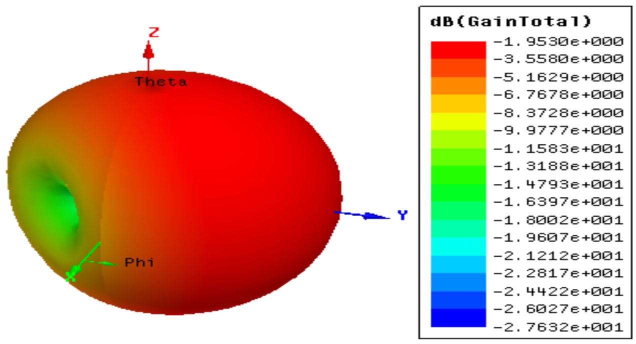

Fig. 7 (b): 3-D polar plot at 5.6 GHz.

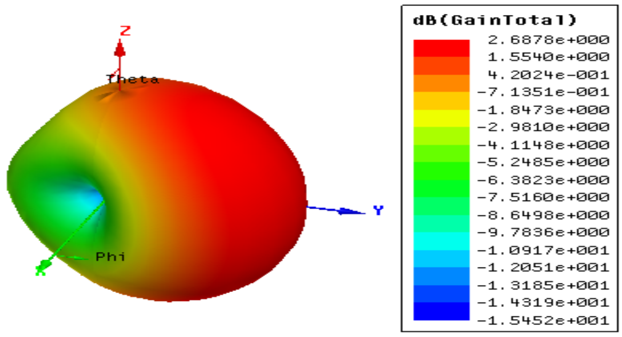

Fig. 7 (c): 3-D polar plot at 10.6 GHz.

Fig. 7: 3-D polar plots when port 1 excited.

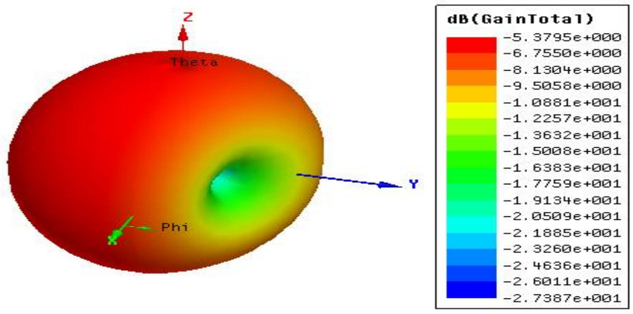

Fig. 8 (a): 3-D polar plot at 3.1 GHz.

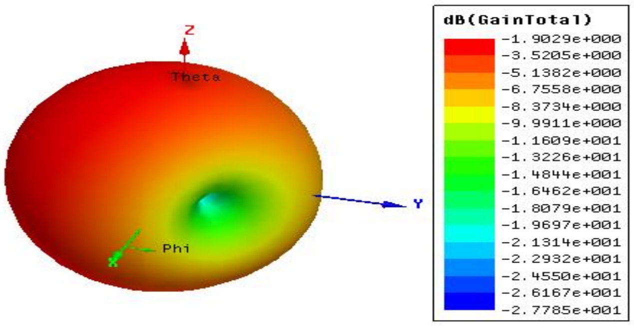

Fig. 8 (b): 3-D polar plot at 5.6 GHz.

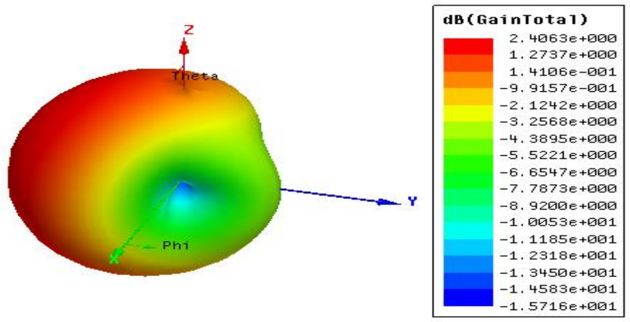

Fig. 8 (c): 3-D polar plot at 10.6 GHz

Fig. 5: 3-D polar plots when the port 2 is excited.

ECC measures the similarity between the antenna radiations. For the proposed antenna the simulated ECC is computed using the Equation (1) for 2-port network proposed by Blanch in [15]. Figure 9 shows the proposed antenna ECC which is low in the designed UWB range. Figure 10 show that the maximum peak gain of the proposed antenna is ranging between 0.4 dBi to 7 dBi in the UWB band. Figure 11 show that the proposed antenna has the maximum efficiency of about 96% over the UWB range.

$$ECC = \frac{|S_{11}^{*}S_{12} + S_{21}^{*}S_{22}|^2}{\left(1-(|S_{11}|^2+|S_{21}|^2)\right)\left(1-(|S_{22}|^2+|S_{12}|^2)\right)}, \qquad (1)$$

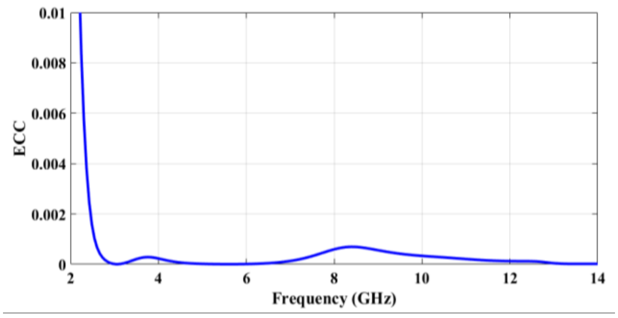

Fig. 9: ECC of the simulated antenna

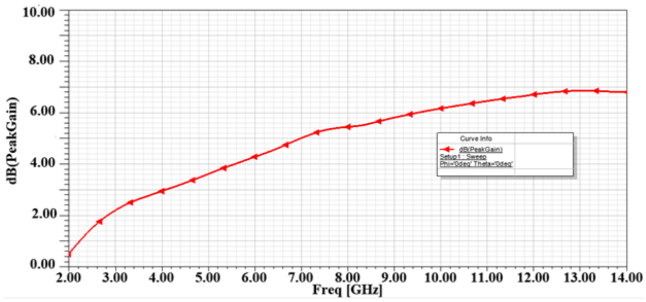

Fig. 10: Peak gain of the simulated antenna.

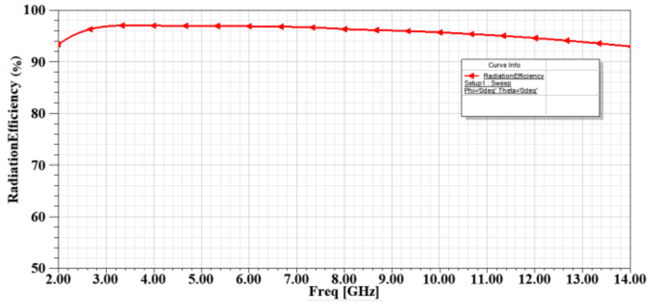

Fig. 11: Radiation efficiency of the simulated antenna.

4. Conclusion

A compact multi input multi output ultra-wideband antenna for wireless portable device communications is proposed in this paper. To symmetrical disc loaded curved elliptical shaped monopoles and common ground with a Y slot and T shaped stub constitute the ultra wideband MIMO antenna. The antenna is fed by coplanar waveguide feed. The proposed antenna is giving best impedance matching ($|S_{11}| < -10$dB) from 2.8 GHz to 12 GHz, an improved isolation of -27dB, a very low ECC of below 0.002, reasonable peak gain of 7 dBi and good efficiency of above 90%. The obtained results shows that the designed MIMO UWB antenna is well fitted for portable device communications.

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