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BROADBAND DESIGN AND SIMULATION OF TRAPEZOIDAL SLOT OF MICROSTRIP ANTENNA

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ABSTRACT
A trapezoidal slot antenna is presented in this work, The design of RMSA is done for different dimensions and locations of single trapezoidal slot that was loaded on the rectangular patch antenna and the selection is based upon the dimension and location giving a better performance of microstrip antenna, the impedance, VSWR and radiation characteristics of this antenna are studied. Simulation results indicate that overall BW is increased by (500 MHz) with the best dimensions (Ws = 2.375mm, and Ls = 22.8877mm) and location of slot is (Fd = 7.51775mm) upper the feed probe. This method is employed for analysis at the frequency band of 2 GHz - 3 GHz. There are gave a good VSWR less than (2), return losses (RL) less than (- 10 dB). This analysis is simulated using applied wave research (*AWR*) package.

Keywords: trapezoidal slot, microstrip antenna, bandwidth, VSWR.

1. INTRODUCTION
The purpose of this work is to design a microstrip patch antenna with trapezoidal slot using applied wave research (*AWR*) package [1].

The specifications for the design purpose of the structure in applied wave research (*AWR*) package are as follows: Input impedance: 50 Ω, resonance frequency: 2.2 - 2.7GHz.

1.1 Project frequency in GHz

Range	Start	Stop	Step
2-3	2	3	0.1

1.2 Enclosure in mm

X-dimension	Y-dimension	X-division	Y-division	X-cell	Y-cell
27.6	38	64	64	0.43125	0.59375

X-dimension	Y-dimension	X-division	Y-division	X-cell	Y-cell
55.2	76	128	128	0.43125	0.59375

1.3 Dielectric layers

It	Thickness mm	er	Loss tangent	Bulk Cond (S/M)	View scale
1	10	1	0	0	1
2	6	4.4	0.0005	0	1

The arrangement of an arbitrary shaped patch microstrip antenna is given in Figure-1. It consists of patch, substrate, ground plane and feeding point. A patch is a two-dimensional antenna element, which is often rectangular in shape. It is of a very thin thickness (t) of metallic strip on top of a material known as the substrate with thickness h (h « λo, usually 0.003λo≤h≤0.05λo, where λo is free space wavelength) above a ground plane [2].

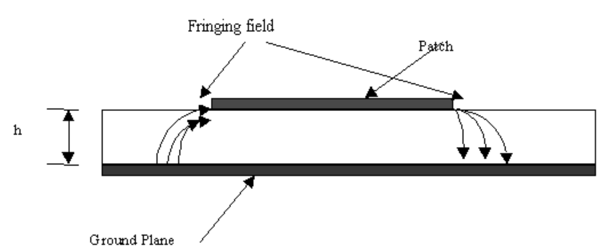

Figure-1. MSA configurations.

VSWR is a very popular parameter for determining the BW of a particular antenna configuration (1≤ VSWR ≤ 2) as an acceptable interval for determining the BW of the antenna. BW is presented more concisely as a Percentage where:

VOL. 7, NO. 1, JANUARY 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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$$BW\ \% = \frac{\Delta f}{f_o} \times 100\ \% \quad (1)$$

Where Δf is the width of the range of acceptable frequencies, and fo is the resonant frequency of the antenna [3].

The expressions for approximately calculating the percentage BW of the RMSA in terms of patch dimensions and substrate parameters is given by:

$$\%\text{BW} = \frac{Ah}{\lambda_0\sqrt{\epsilon_r}}\sqrt{\frac{W}{L}} \quad (2)$$

Where

$$A = 180 \text{ for } \frac{h}{\lambda_0\sqrt{\epsilon_r}} \leq 0.045$$

$$A = 200 \text{ for } 0.045 \leq \frac{h}{\lambda_0\sqrt{\epsilon_r}} \leq 0.075$$

$$A = 220 \text{ for } \frac{h}{\lambda_0\sqrt{\epsilon_r}} \geq 0.075$$

Where

W and *L* are the width and length of the RMSA. With an increase in *W*, BW increases. However, *W* should be taken less than *L* to avoid excitation of higher order modes. For other regularly shaped patches, values of equivalent *W* can be obtained by equating the area with that of the RMSA as described in [4, 5].

It was got a good enhancement of bandwidth of Rectangular patch antenna with Trapezoidal slot but without concentrate upon the best values for (VSWR, RL and Zin) [6].

In this paper the technique for extending the bandwidth is studied. The first is loading the rectangular patch by trapezoidal slot that means it has two parameters that have effect on the antenna performance, the length of the slot and the width as shown in Figure-2.

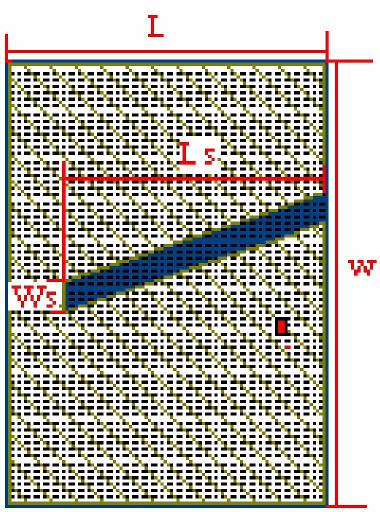


Figure-2. Top view of patch antenna with trapezoidal slot has two dimensions (Ws and Ls).

The second is simulating and testing different dimensions and locations of single trapezoidal slot and check the effect of these on the performance of RMPA by analyzing the parameters (RL, VSWR, input impedance, E-field and H-field).

This technique is used to design microstrip antenna working in the (2-3) GHz range frequency.

The design was simulated using the applied wave research (*AWR*) package. It was found that for loading the antenna with trapezoidal slot in the rectangular patch gives the widest bandwidth (about 500 MHz).

2. DESIGN OF RMSA

Here, the "Transmission Line Model" [3] has been used to predict the radiation characteristics of the patch.

RMPA operating of resonance frequency (2.4GHz) for TM10 mode, with the coaxial probe feed used the antenna is matched by choosing the proper feed position [7].

The width of the patch can be calculated from the equation by [8].

The effective dielectric constant (ε_{eff}) is less than (ε_r), the difference in the length (ΔL) and the actual length (L) which is given by [9].

The dimensions of ground plane (Lg and Wg) are given by [10].

To improving the BW, a trapezoidal slot is used; it has three parameters that have effect on the antenna performance, the length of the slot, the width of slot and the locations of slot.

3. GEOMETRY OF RMSA WITH TRAPEZOIDAL SINGLE SLOT

The geometries of design is shown in Figure-3, the FR4-based substrate having εr = 4.4 is h = 6mm in thickness, 27 mm along the *x*-axis and 38mm along the *y*-axis. The feed probe (coaxial) has a characteristic impedance of 50 ohms.

The patch is a rectangle that is 27.6 mm along the x-axis and 38 mm along the y-axis. The rectangular part of the ground plane is (55.2 mm×76 mm).

A coaxial probe is used to connect the inset microstrip at its centre axis and away from the patch edge.

Where the input impedance is nearly 50 ohm then $Y_f = Y/2 = 19$ mm along the length, and $X_f = X/4 = 7.174$ mm along the width. When trial and error are used, it was found the best impedance match at feed point locations are (22.5625mm) of the upper edge of the patch and (2.5875mm) of the right edge of the patch at an input impedance of (50 - j 0.188) ohms.

The vertical distance (Fd) between the probe feed and the trapezoidal slot is (7.51775mm).

Applied wave research (*AWR*) package was configured with the following specifications: the number of divisions is 128 divisions, X cell size= 0.43125cm and Y cell size = 0.59375 cm, x-division = 128 and y- division = 128.

VOL. 7, NO. 1, JANUARY 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

A single trapezoidal slot with dimensions (Ws = 2.375mm, and Ls = 22.8877mm) as shown in Figures (3).

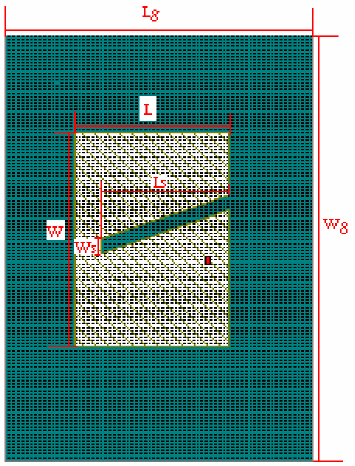


Figure-(3-a). Top view of single trapezoidal slot of RMPA.

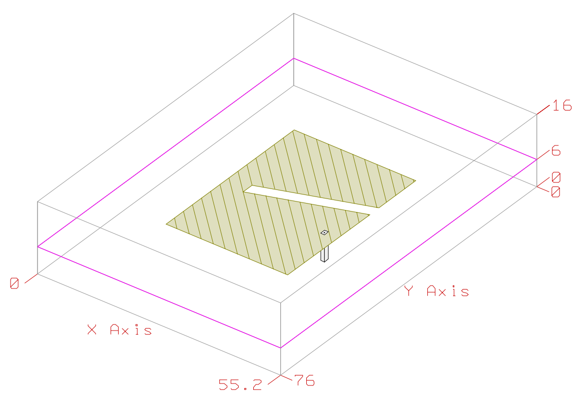


Figure-(3-b). Three - dimensions of single trapezoidal slot of RMPA.

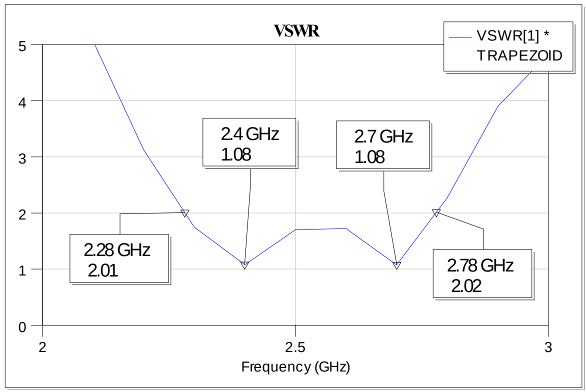
Single trapezoidal slots with different dimensions and locations were set in the package to get the best results compute in Table-1.

Table-1. Single trapezoidal slot has the different dimensions and locations.

It	Ws mm	Ls mm	Fd mm
1	2.96875	24.1244	7.125
2	2.67188	24.1244	7.125
3	2.375	23.941	7.51775
4	2.96875	24.1244	7.71875
5	3.5625	24.1244	8.3236
6	2.96875	24.1244	8.3125

4. RESULTS

The Applied Wave Research 2004 package computed returns losses RL ≤ -10, the VSWR is given in Figures (4a, 4b, 4c, 4d, 4e and 4f)) the bandwidth of design for VSWR ≤ 2 are (500, 490, 470, 450, 440, 440) MHz, respectively.



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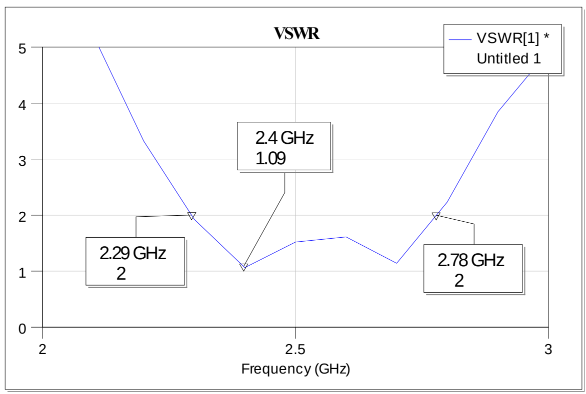
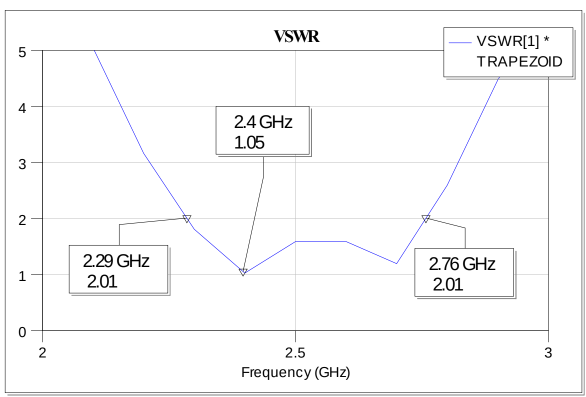


(b)



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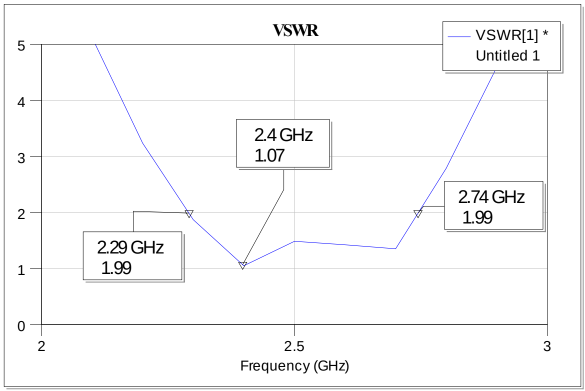

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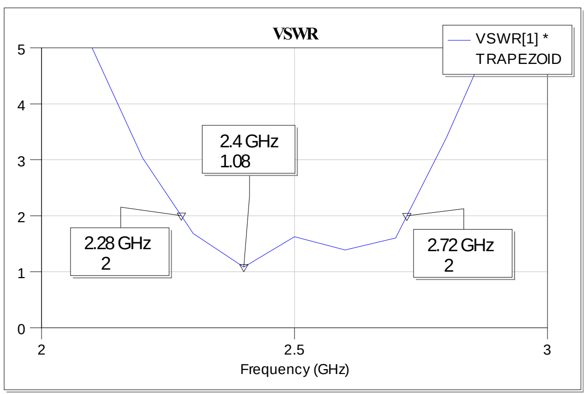

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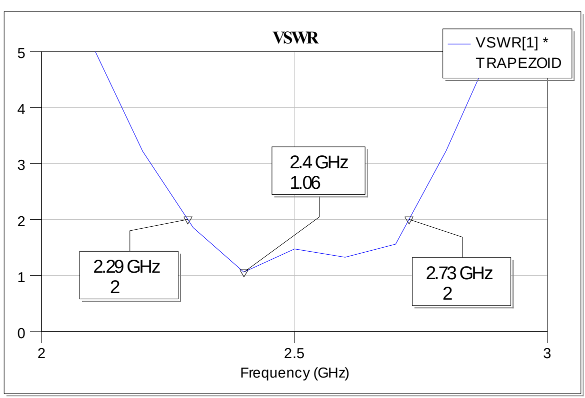
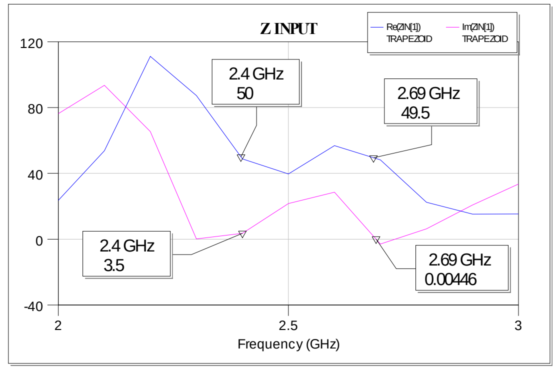


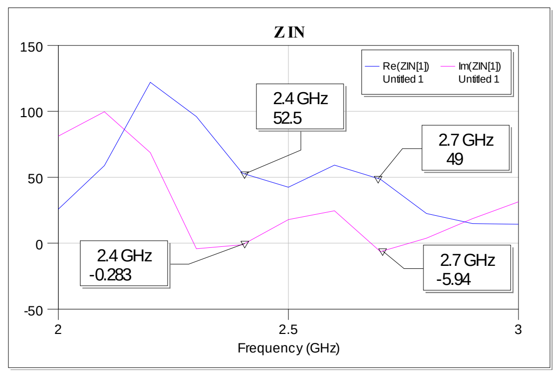
(f)

Figure-4. VSWR of the antenna with different dimensions and locations of single slot.

The Applied Wave Research 2004 package computed input impedance of the design is depicted in Figures (5a, 5b, 5c, 5d, 5e and 5f), respectively. The real part of the impedance is closer to 50 ohm and the imaginary part to - 0.188 ohm.



(a)



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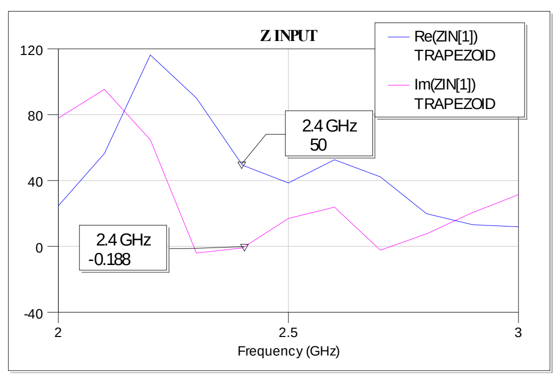

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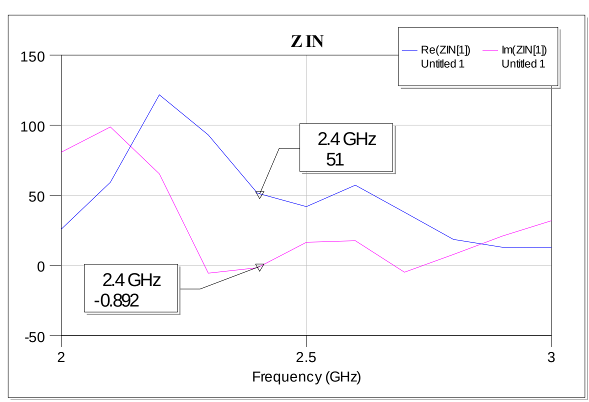

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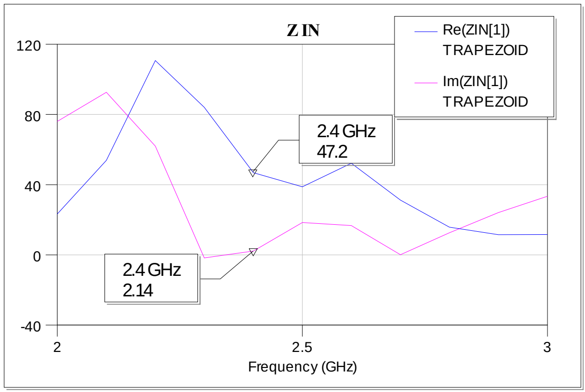

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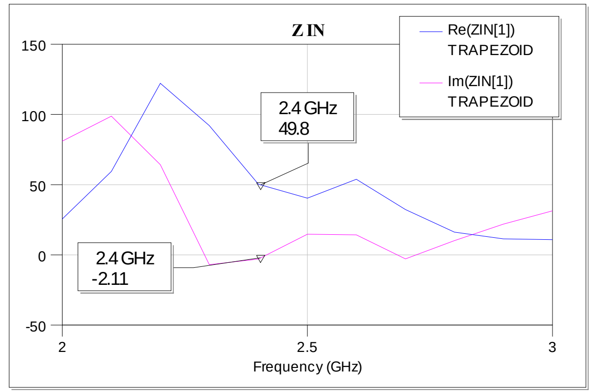
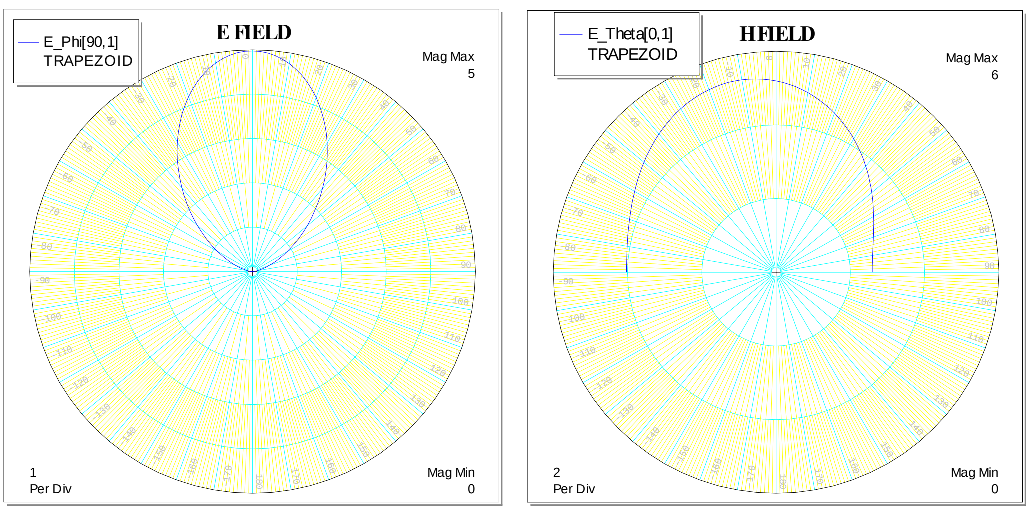


(f)

Figure-5. The input impedance of the antenna with different dimensions and locations of single slot.

The Applied Wave Research 2004 package computed the radiation patterns of design in the x-z plane (E-plane) and y-z (H-plane) in Figures (6a, 6b, 6c, 6d, 6e and 6f), respectively.



(a)

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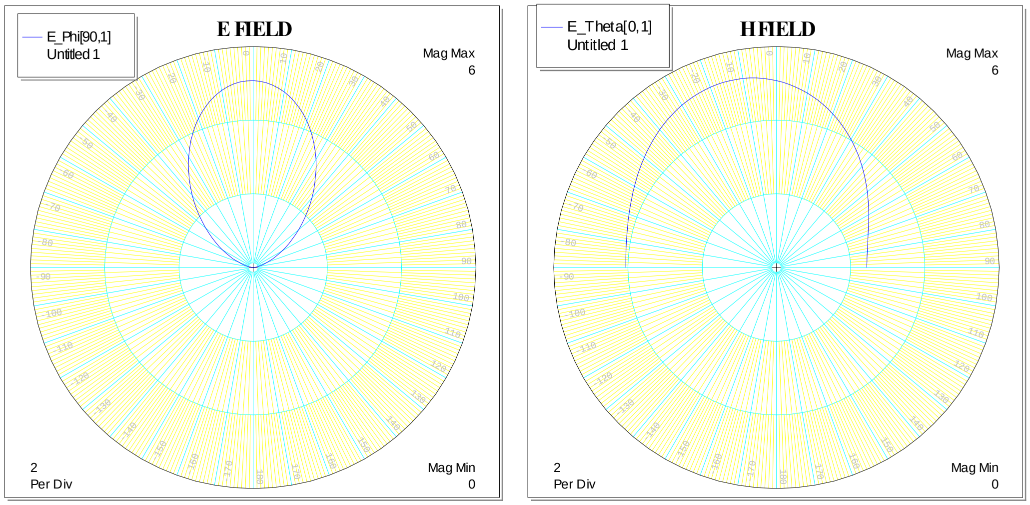

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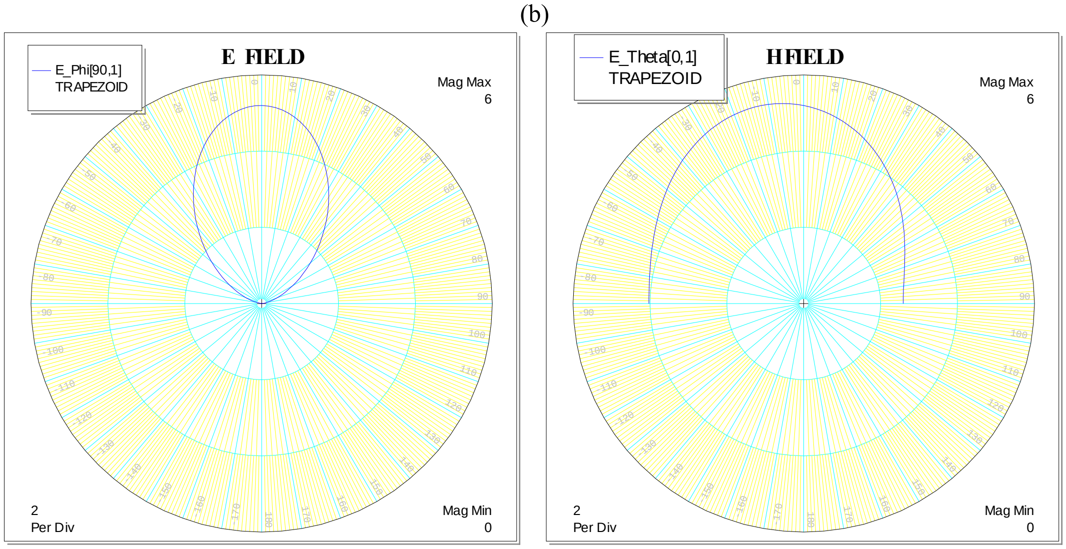

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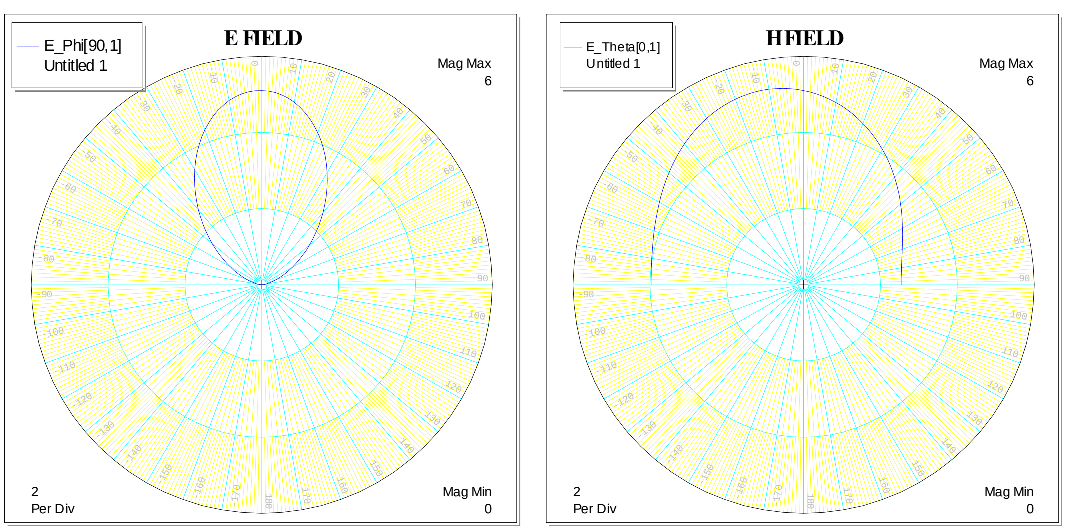

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VOL. 7, NO. 1, JANUARY 2012 ISSN 1819-6608
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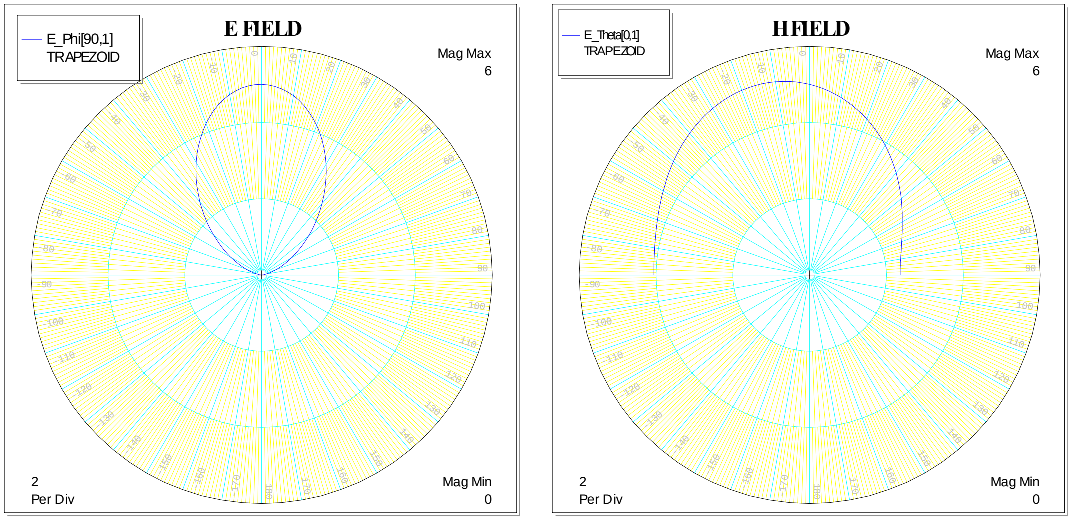

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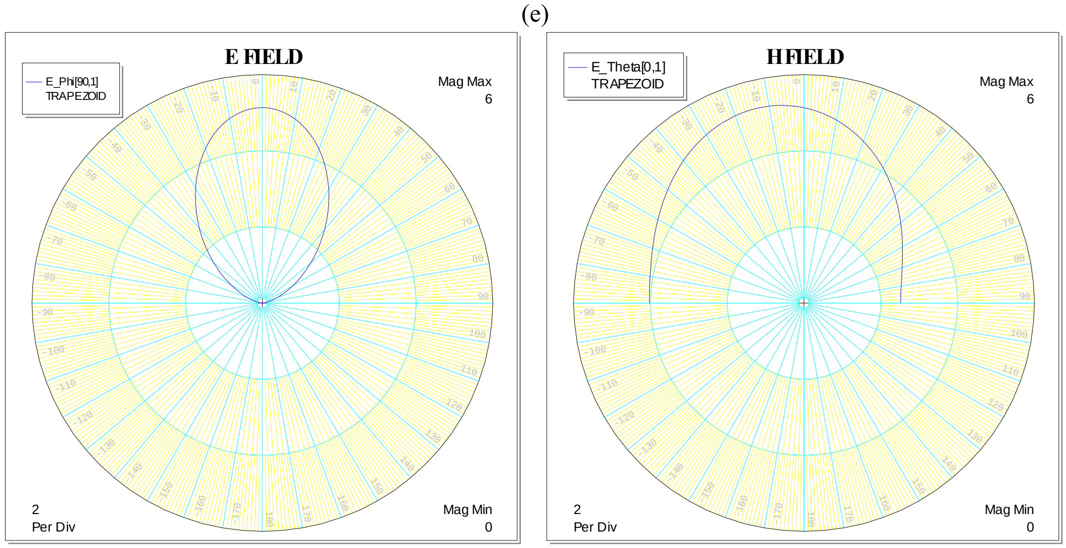
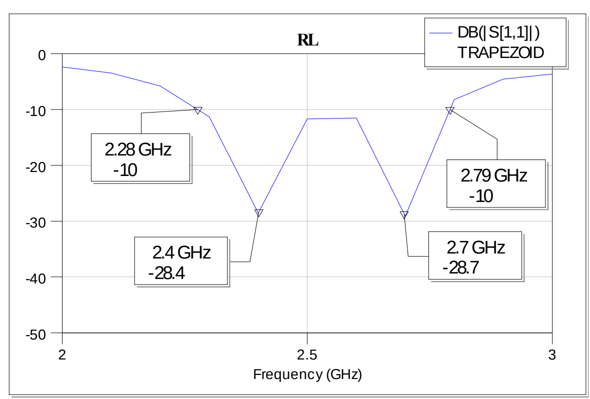


(f)

Figure-6. The radiation pattern of microstrip with different dimensions and locations of single slot.

The Applied Wave Research 2004 package computed returns losses RL ≤ -10, RL is given in Figures (7a, 7b, 7c , 7d, 7e and 7f) the bandwidth of design for VSWR ≤ 2 are (510, 490, 500, 480, 470 and 450) MHz, respectively.



(a)

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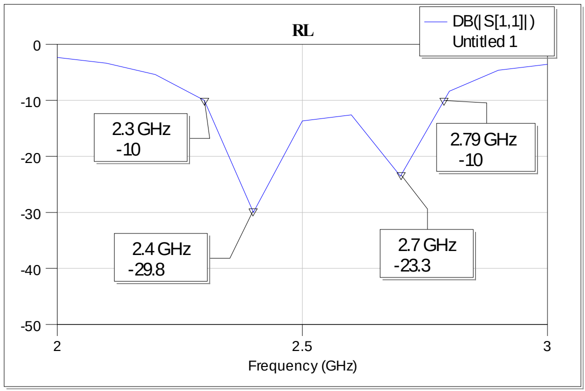

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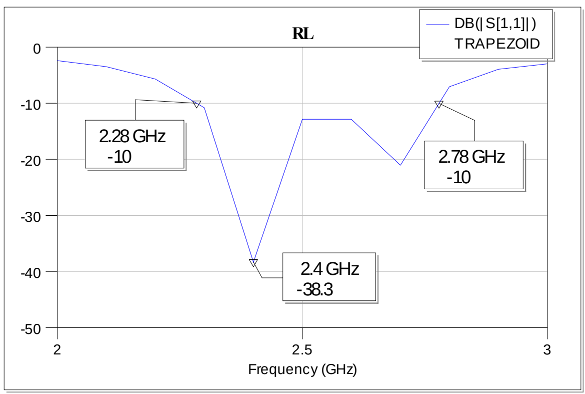

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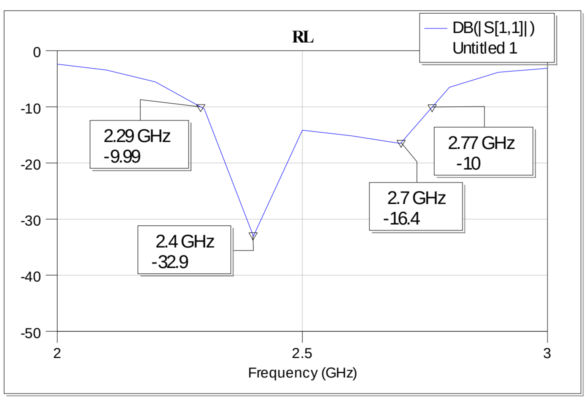

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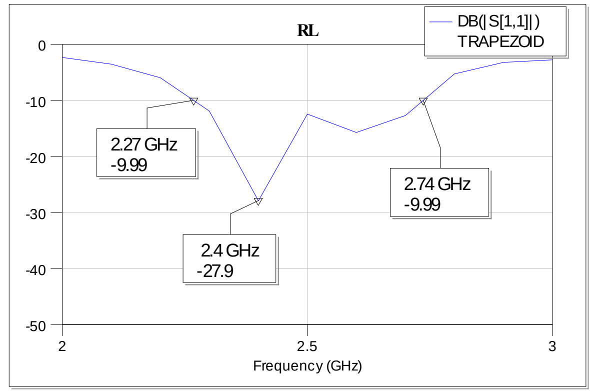

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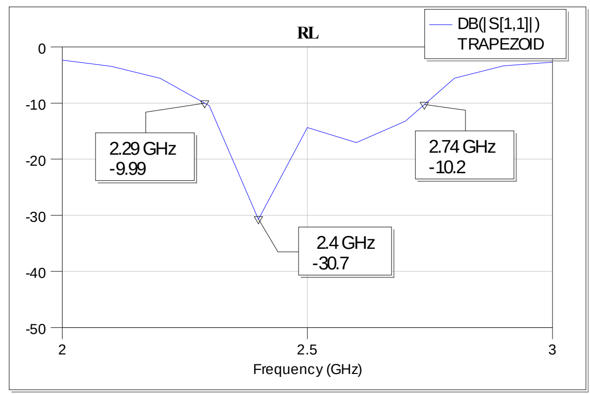

(f)

Figure-7. Return losses (RL) of the antenna with different dimensions and locations of single slot.

The bandwidth can be calculated from the VSWR plot. From Figures-4 (a, b, c, d, e and f), at Figure-4(a), the simulated impedance bandwidth of (500 MHz 20.83%) is achieved at (VSWR ≤ 2). At Figure-4(b), the simulated impedance bandwidth of (490 MHz 20.41 %) is achieved at (VSWR ≤ 2). At the Figure-4(c), the simulated impedance bandwidth of (470 MHz 19.58%) is achieved (VSWR ≤ 2). At Figure-4(d), the simulated impedance bandwidth of (450 MHz 18.75 %) is achieved (VSWR ≤ 2). At Figure-4(e), the simulated impedance bandwidth of (440 MHz 440 %) from (2.2921) GHz to (2.6063) GHz is achieved at (VSWR ≤ 2). At Figure-4(f), the simulated impedance bandwidth of (440 MHz 440 %) is achieved at (VSWR ≤ 2).

The impedance can be calculated from the impedance plot. From Figures-5 (a, b, c, d, e and f), at Figure-5(a), the simulated impedance of (50 + j 3.5) Ω is achieved at (-28.4 dB) return losses (VSWR ≤ 2). At Figure-5(b), the simulated impedance bandwidth of (52.5-j0.283) Ω is achieved at (-29.8 dB) return losses (VSWR ≤ 2). At the Figure-5(c), the simulated impedance bandwidth of (50 - j 0.188) is achieved at (-38.3dB) return losses (VSWR ≤ 2). At Figure-5(d), the simulated impedance bandwidth of (51 - j 8.92) is achieved at (- 32.9 dB) return losses (VSWR ≤ 2). At Figure-5(e), the simulated impedance bandwidth of (47+ j 2.14) is achieved at (- 27.2 dB) return losses (VSWR ≤ 2). At Figure-5(f), the simulated impedance bandwidth of (50 - j 0.188) is achieved at (-30.7dB) return losses (VSWR ≤ 2).

The bandwidth can be calculated from the Return losses RL plot. From Figures-7 (a, b, c, d, e and f), at Figure-7(a), the simulated impedance bandwidth of (510 MHz 21.25%) is achieved at (-28.4 dB) return losses. At Figure-7(b), the simulated impedance bandwidth of (490 MHz 20.41 %) is achieved at (-29.8 dB)) return losses at the Figure-7(c). The simulated impedance bandwidth of (500 MHz 20.83%) is achieved at (-38.3dB) return losses. At Figure-7(d), the simulated impedance bandwidth of (480 MHz 20 %) is achieved at (- 32.9 dB) return losses. At Figure-7(e), the simulated impedance bandwidth of (440 MHz 18.33 %) is achieved at (- 27.2 dB) return losses. At Figure-7(f), the simulated impedance bandwidth of (450 MHz 18.75 %) is achieved at (-30.7dB) return losses.

Table-2. The Effect of dimensions and locations of trapezoidal slot on the bandwidth of microstrip antenna.

It	Ws mm	Ls mm	Fd mm	Fo GH	BW MHZ	BW %
1	2.96875	24.1244	7.125	2.4	510	21.25
2	2.67188	24.1244	7.125	2.4	490	20.41
3	2.375	23.941	7.51775	2.4	500	20.83
4	2.96875	24.1244	7.71875	2.4	480	20
5	3.5625	24.1244	8.3236	2.4	440	18.33
6	2.96875	24.1244	8.3125	2.4	450	18.75

5. CONCLUSIONS

In this work, the Applied Wave Research 2004 package is used for determining the proper location of a proper feed and trapezoidal single slot. The simulations results for trapezoidal slot have dimensions (Ws=2.375 mm) and (Ls=19.873) at locations (23.75 mm) from upper edge of rectangular patch gives a good (VSWR ≤ 2) at (-10dB) return losses and good impedance bandwidth of (500 MHz 20.83%) the frequency band of 2 GHz - 3 GHz.

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