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STUDY AND ANALYSES OF RECTANGULAR SINGLE SLOT MICROSRIP ANTENNA

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ABSTRACT

This paper focuses the study and analysis of a rectangular single slot patch antenna with a probe feed. The analysis is simulated with microwave office 2004 software package. The analysis method is employed at the frequency band of 1GHz - 3GHz. There give a good VSWR less than 2, return losses (RL) less than (- 10 dB) and impedance bandwidth of the order of (15.416) at the frequency band of (2.29 -- 2.66) GHz of 2-3 GHz.

Keywords: microstrip antenna, rectangular slot, bandwidth, performance, VSWR.

1. INTRODUCTION

An MSA in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. The top and side views of a *rectangular MSA* (RMSA) are shown in Figure-1. [1].

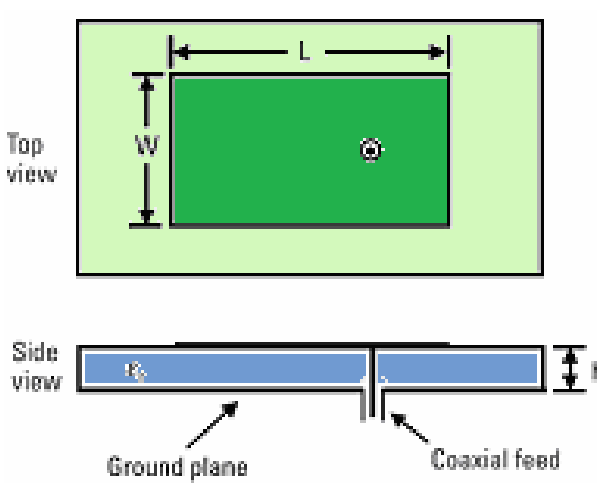

Figure-1. MSA configurations.

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

$$\%BW = \frac{Ah}{\lambda_0\sqrt{\epsilon_r}}\sqrt{\frac{W}{L}} \qquad (1)$$

Where

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

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

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

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 [2, 3].

Another simplified relation for quick calculation of BW (in megahertz) for VSWR = 2 of the MSA operating at frequency *f* in gigahertz, with *h* expressed in centimetres, is given by [4]

$$BW \cong 50hf^2 \qquad (2)$$

In this paper, the method of calculation used is:

$$\% BW = (f2 - f1) / fo \qquad (3)$$

Where,

f1 = the first frequency of the bandwidth
f2 = the final frequency of the bandwidth
fo = the resonance frequency

Although microstrip antennas have many attractive advantages, it has a narrow bandwidth. Many techniques have been used to enhance the bandwidth. Among these techniques are using thick foam or air substrates. Other techniques for enhancing the bandwidth of a single-layer single-patch microstrip antenna include the designs with single rectangular slot with probe feed [5].

The best value of the bandwidth is achieved when Ls =20.16mm (inside the dielectric substrate at operating frequency 2.4GHz) at which the bandwidth is 250MHz (10.80% of the center frequency) [6].

In this paper the technique for extending the bandwidth is studied. The first is loading the rectangular patch by rectangular 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

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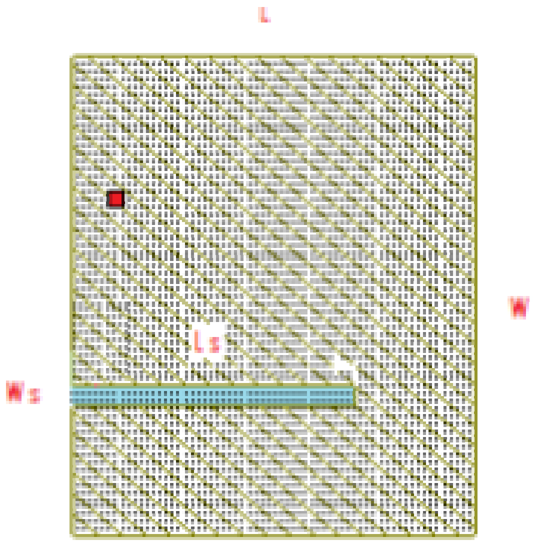

Figure-2. Top view of patch antenna with rectangular slot has two dimensions (Ws and Ls).

The second is simulating and testing different dimensions and locations of single rectangular 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 2004 microwave package. It was found that for loading the antenna with rectangular slot in the rectangular patch gives the widest bandwidth (about 370 MHz).

2. DESIGN STRUCTURE PARAMETERS

In this presented work, transmission line method is used to analyze the rectangular microstrip antenna [7].

RMPA operating of resonance frequency (2.4 GHz) for TM10 mode, with the coaxial probe feed is matched by choosing the proper feed position [8].

The width of the patch can be calculated from the equation by [9].

The effective dielectric constant (εeff) is less than (εr) i.e the difference in the length (ΔL) and the actual length (L) which is given by [10].

The dimensions of ground plane (Lg and Wg) are given by [11].

Feeding technique influences the input impedance and characteristics of the antenna, and is an important design parameter. The centre conductor of the coaxial connector is soldered to the patch. The main advantage of this feed is that it can be placed at any desired location inside the patch to match with its input impedance.

To increase the BW, a rectangular 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. ANTENNA GEOMETRY

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 Yf = Y/2 = 19 mm along the length, and Xf = X/4 = 7.174 mm along the width. When trial and error are used, it was found the best impedance match at feed point location is (3.45 mm) of the left edge of the patch and (11.2812) is of the upper edge of the patch, at an input impedance of (50.1 + j 2.6) ohms.

The vertical distance (FD) between the probe feed and the rectangular slot is (11.2812 mm).

The microwave office software 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.

A single rectangular slot with dimensions (Ws = 5.12 mm, and Ls = 21.1313mm) as shown in Figures 3, 4.

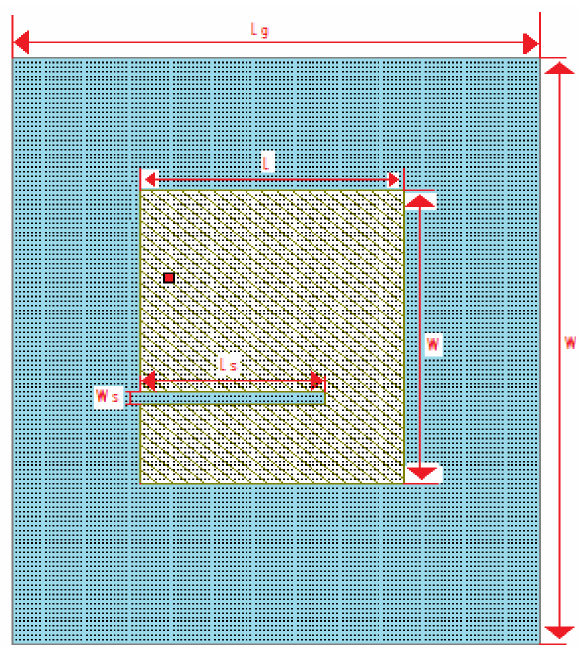

Figure-3. Top view of single rectangular slot of RMPA.

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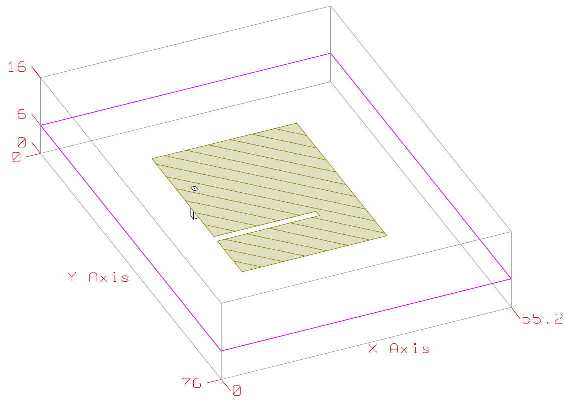


Figure-4. Three - dimensions of single rectangular slot of RMPA.

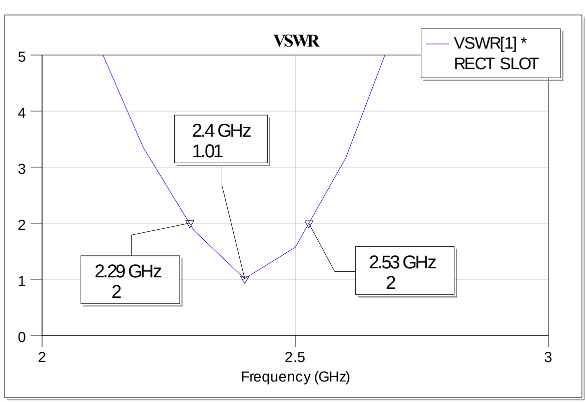
Single rectangular slots with different dimensions and locations were set in the package to get the best results compute in Table-1.

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

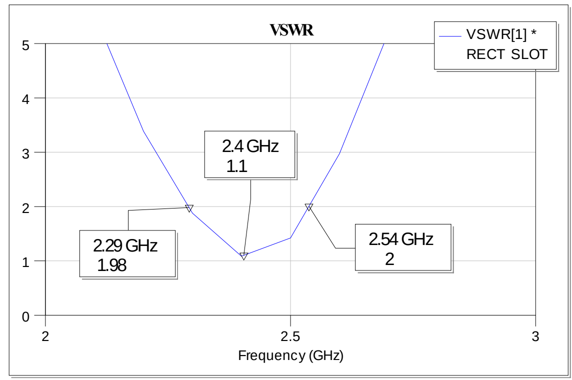
It	Ws (mm)	Ls (mm)	Fd (mm)
1	2.1	19.4036	-14.25
2	3.85	20.7	-12.47
3	4.1	20.7	-12.4688
4	9.5	19.4062	-11.875
5	5.12	21.1313	-11.2812
6	1.1875	20.7	+10.0938

4. RESULTS

The microwave office package computer returns losses RL $\leq$ -10, the VSWR is given in Figures (4a, 4b, 4c, 4d, 4e and 4f) the bandwidth of design for VSWR ≤ 2 are (240, 250, 310, 320, 350 and 300) MHz, respectively.



(a)



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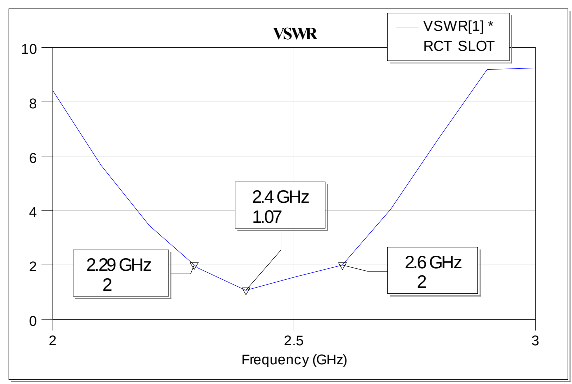

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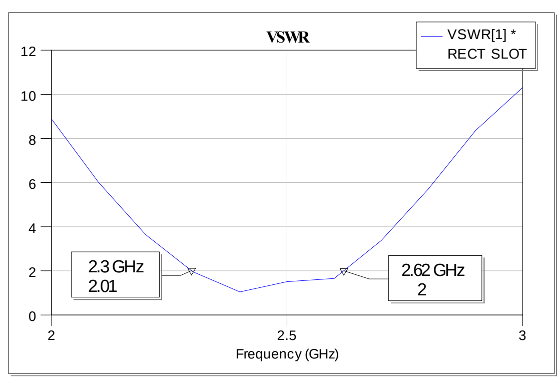

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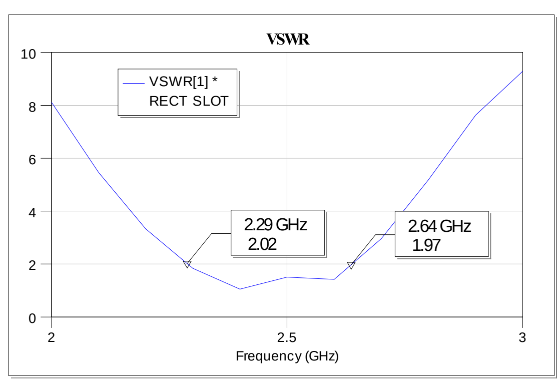

(e)

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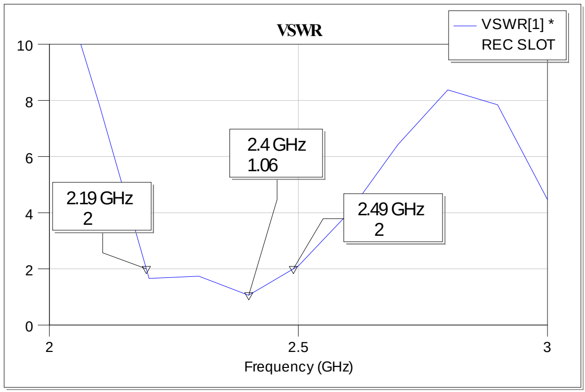
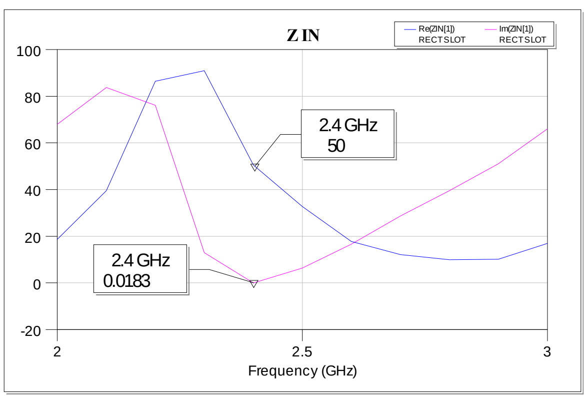


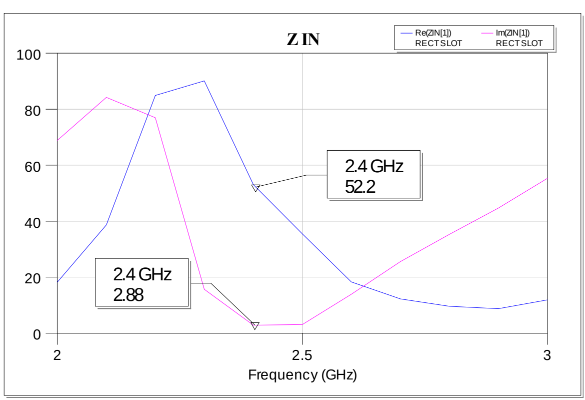
(f)

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

The microwave office-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 50.1 ohm and the imaginary part to 2.63 ohm.



(a)



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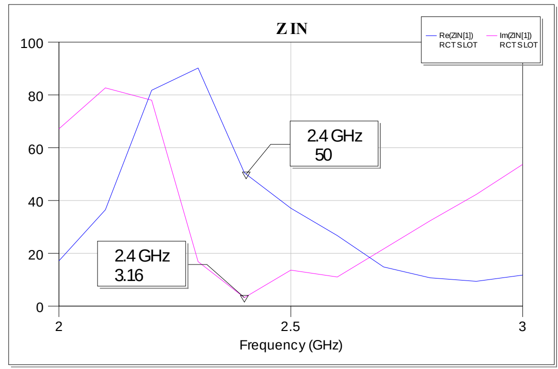

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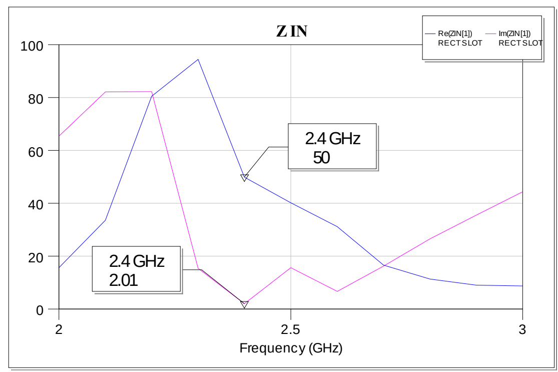

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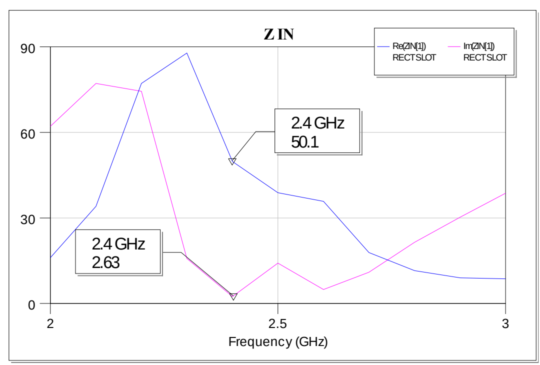

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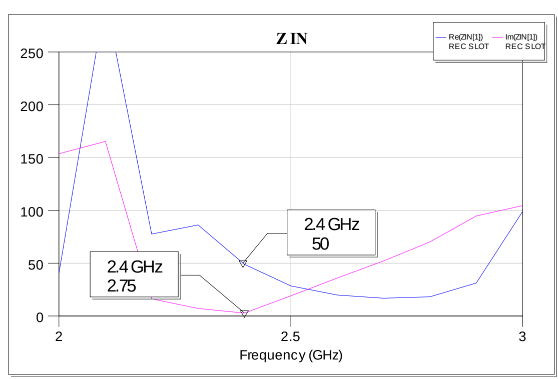

(f)

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

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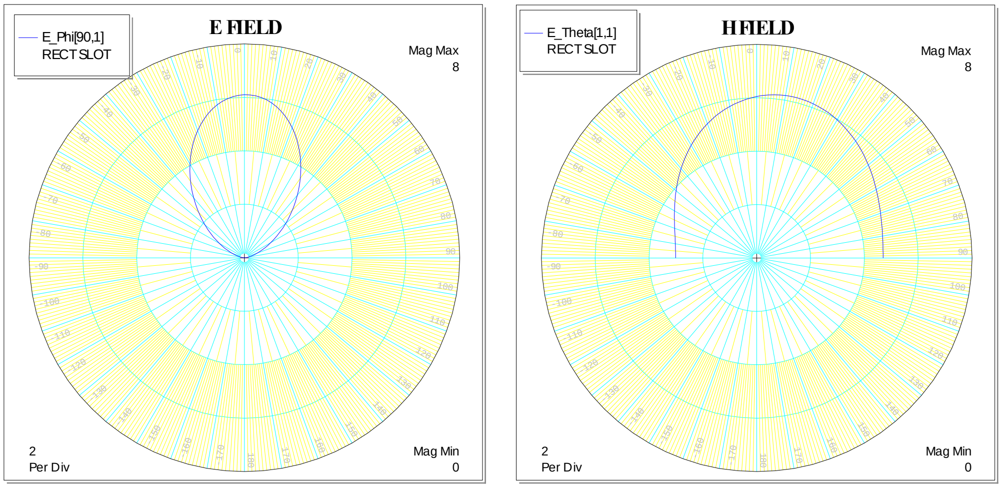
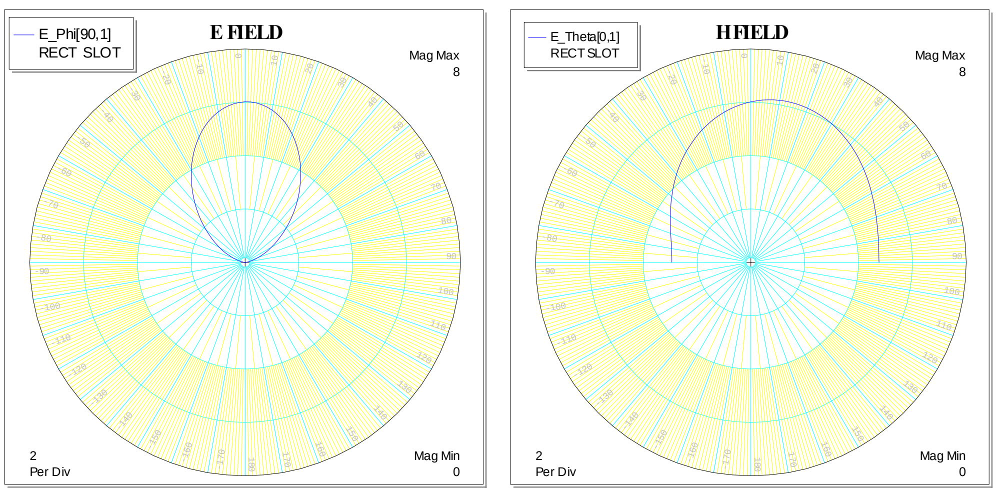
The microwave office-computed the radiation patterns of design in the x-z plane (E-plane) and y-z (H-plane) in Figures (6a, 6b, 6c and 6d), respectively.



(a)



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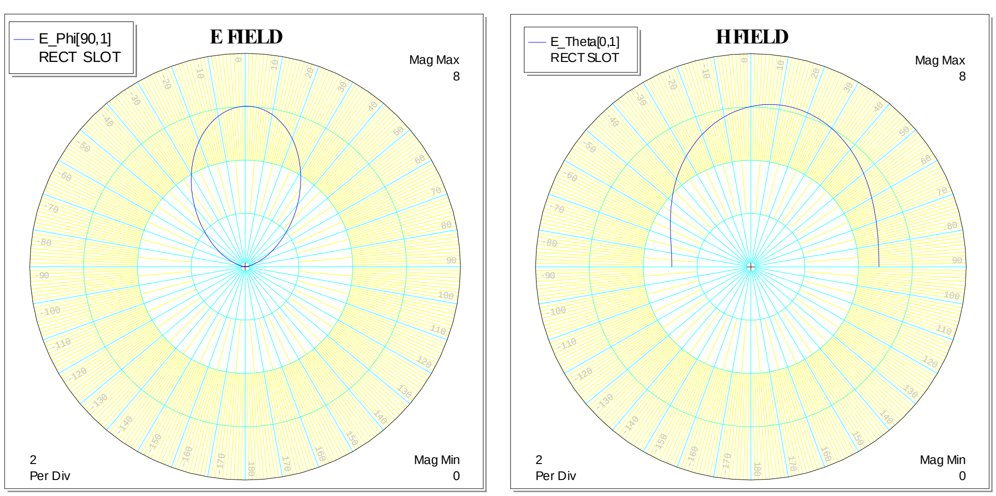

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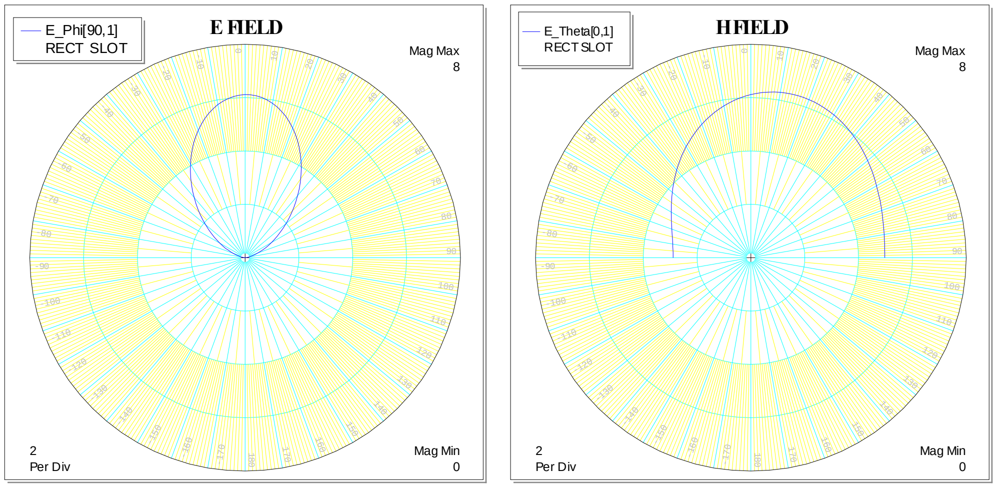

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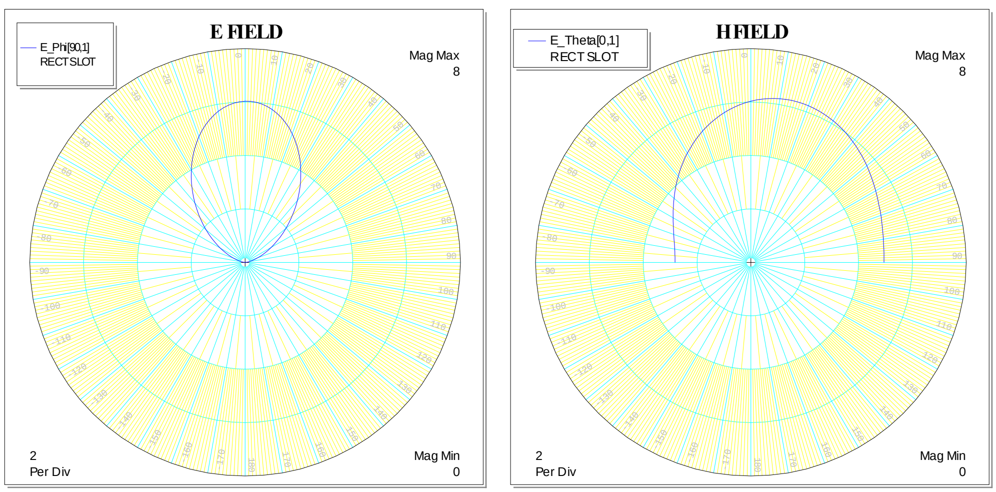

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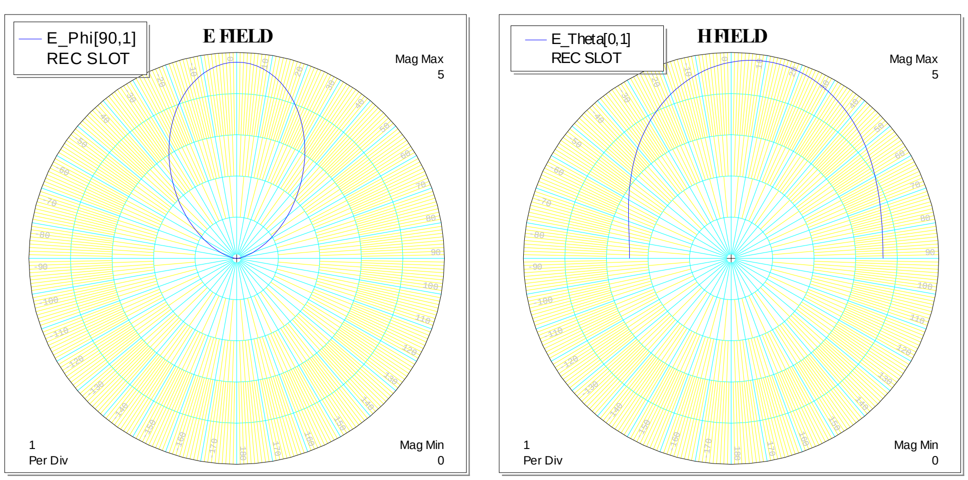

(f)

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

The microwave office package computer returns losses RL ≤ -10, RL is given in Figures (7a, 7b, 7c, 7d, 7e and 7f) the bandwidth of design for VSWR ≤ 2 are (250, 270, 290, 330, 370 and 320) MHz, respectively.

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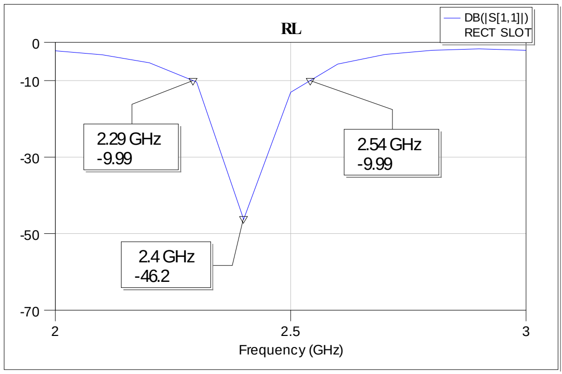
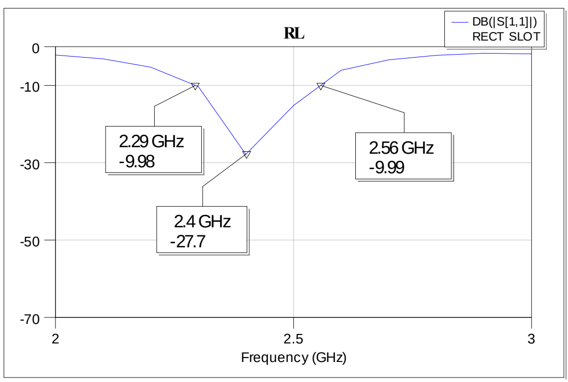


(a)



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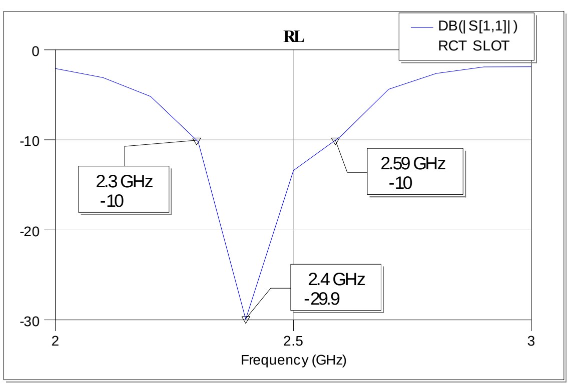

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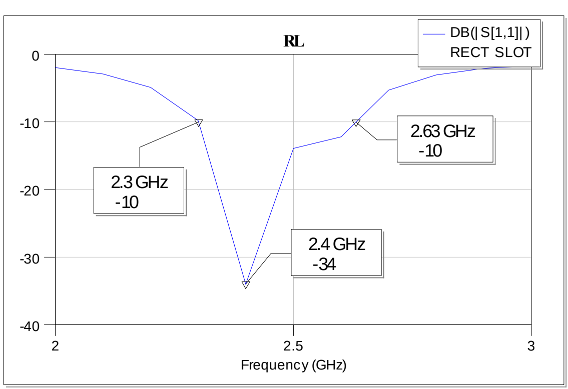

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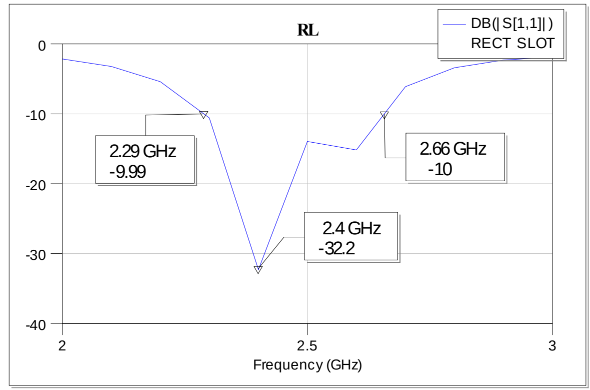

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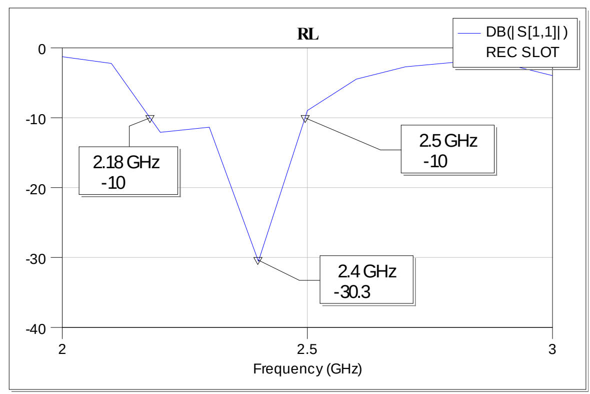

(f)

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

The bandwidth can be calculated from the (RL) plot. From Figures 4 (a, b, c, d and f), at Figure-4a, the simulated impedance bandwidth of (250 MHz 10.41%) from (2.29) GHz to (2.54) GHz is achieved at (-10dB) return losses (VSWR ≤ 2). At Figure-4b, the simulated impedance bandwidth of (270 MHz 11.25 %) from (2.29) GHz to (2.56) GHz is achieved at - (10dB) return losses (VSWR ≤ 2). At Figure-4c, the simulated impedance bandwidth of (290MHz 12.08%) from (2.30) GHz to (2.59) GHz is achieved at (-10dB) return losses (VSWR ≤ 2). At Figure-4d, the simulated impedance bandwidth of (330 MHz 13.75 %) from (2.30) GHz to (2.63) GHz is achieved at - (10dB) return losses (VSWR ≤ 2). At Figure-4e, the simulated impedance bandwidth of (370MHz 15.416 %) from (2.29) GHz to (2.66) GHz is achieved at - (10dB) return losses (VSWR ≤ 2). At Figure-4f, the simulated impedance bandwidth of (320MHz 13.333 %) from (2.18) GHz to (2.5) GHz is achieved at - (10dB) return losses (VSWR ≤ 2).

Table-2. The effect of dimensions and locations of rectangular slot on the bandwidth of microstrip antenna.

It	Ws (mm)	Ls (Mm)	Fd (mm)	Fo (GH)	BW (MHZ)	BW (%)
1	2.1	19.4036	-14.25	2.4	250	10.41
2	3.85	20.7	-12.47	2.4	270	11.25
3	3.85	20.7	-12.4688	2.4	290	12.08
4	9.5	19.406	-11.875	2.4	330	13.75
5	5.12	21.1313	-11.2812	2.4	370	15.416
6	1.1875	20.7	+10.0938	2.4	320	13.333

5. CONCLUSIONS

In this work, the MW-office 2004 package is used for determines the proper location of a proper feed and rectangular single slot. The simulations results for rectangular slot have dimensions [Ws=5.12mm] and [Ls=21.1313] at location is (3.45 mm) of the left edge of the patch and (11.2812) is of the upper edge of the patch, at an input impedance of (50.1 + j 2.6) ohms.

The vertical distance (FD) between the probe feed and the rectangular slot is (11.2812 mm). It gives a good (VSWR $\leq$ 2) at (-10dB) return losses and good impedance bandwidth of the order of (15.416%) at the frequency band of (2.29- 2.66) GHz of (2-3) GHz.

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