IMPROVING BANDWIDTH RECTANGULAR PATCH ANTENNA USING DIFFERENT THICKNESS OF DIELECTRIC SUBSTRATE

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ABSTRACT

Microstrip patch antenna has some drawbacks of low efficiency, narrow band (<5%), and surface wave losses. In this paper the solution method was used different thickness of dielectric substrate (h = 4, 6 and 8) mm to increase bandwidth, the simulated results for rectangular give bandwidth of (200 MHz) in case (h = 6mm). A rectangular microstrip patch antenna that meets the requirement of operation at (2.4 GHz), the proposed configurations are simulated and analyzed using microwave office 2000 software package. The VSWR, input impedance, radiation patterns and S11 performance are used for the analysis of the different configurations. Feed point on the patch that gives a good match of 50 ohm, input impedance was found by a method of trial and error.

Keywords: Microstrip patch antenna, bandwidth improvement, performance, dielectric substrate.

1. INTRODUCTION

A micostrip patch antenna has the advantages of low cost, light weight, and low profile planner configuration. However, they suffer from the disadvantage of low operating bandwidth [1-2]. Bandwidth improves as the substrate thickness is increased, or the dielectric constant is reduced, but these trends are limited by an inductive impedance offset that increases with thickness. A logical approach, therefore, is to use a thick substrate or replacing the substrate by air or thick foam, the dielectric constants are usually in the range of ($2.2 \leq \varepsilon r \leq 12$) [3-4]. This paper presents the use of transmission line method to analyze the rectangular micro strip antenna [5]. 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 [6].

RMPA is characterized by its length L, width W and thickness h, as shown in Figure-1.

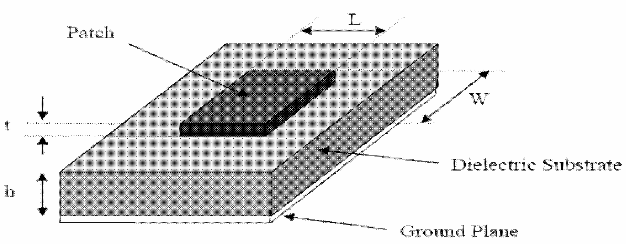

Figure-1. Structure of a rectangular microstrip patch antenna.

It is of a very thin thickness h ($h << \lambda_o$, usually $0.003\ \lambda_o \leq h \leq 0.05\ \lambda_o$) where λ_o is free space wavelength above a ground plane [7].

For rectangular patch, the length L of the element is usually

$\lambda_o / 3 < L < \lambda_o / 2$.

2. TRANSMISSION LINE ANALYSIS METHOD RMPA

In this model the MSA can be represented by two slots of width (W) and height (h) separated by transmission line of length (L).

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

$$W = \frac{c}{2fo\sqrt{(\varepsilon_r + 1)/2}} \quad \text{---------- (1)}$$

The effective dielectric constant (εeff) is less than (εr) because the fringing field around the periphery of the patch is not confined to the dielectric speared in the air also.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\sqrt{\frac{1}{\left[1 + 12\frac{h}{w}\right]}} \quad \text{----- (2)}$$

For TM10 Mode the length of the patch must be less than (λ /2)

This difference in the length (ΔL) which is given empirically by [9].

$$\Delta L = 0.412\, h \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.813\right)} \quad \text{--- (3)}$$

$$Leff = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} \quad \text{---------- (4)}$$

Where c=speed of light, Leff = effective length. Fr=resonance frequency, εeff = effective dielectric constant.

$$L = L_{eff} - 2\Delta L \quad \text{-------- (5)}$$

For a rectangular microstrip patch antenna, the resonance frequency for any TMmn mode is given by James and Hall [10] as:

$$f_o = \frac{c}{2\sqrt{\varepsilon_{eff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{1/2} \quad \text{----- (6)}$$

Where m, n = 0, 1, 2 --- wave number at m,n mode, c=speed of light.

3. DESIGN CONSIDERATION OF RMPA

The designer should have step by step procedure.

Step one

Substrate selection

The first step in the design is to choose a suitable dielectric substrate of appropriate thickness h and loss tangent. A thicker substrate, besides being mechanically strong it will increase the radiated power, reduce the conductor loss and improve impedance bandwidth [11].

Step two

Width and length parameters

A larger patch width increases the power radiated and thus gives decreased resonant resistance, increased BW and increased radiation efficiency. With proper excitation one may choose a patch width W greater than patch length. It has been suggested that 1 < W/ L < 2 [12, 13].

In case of microstrip antenna, it is proportional to its quality factor Q and given by [13] as:

$$BW = \frac{VSWR - 1}{Q\sqrt{VSWR}} \quad \text{-------- (7)}$$

The percentage bandwidth of the rectangular patch microstrip antenna in terms of patch dimensions and substrates parameters is given as follows [13].

$$BW\% = \frac{Ah}{\lambda_o}\sqrt{\frac{W}{L}} \quad \text{--------- (8)}$$

where

$$A = 180 \quad For \quad \frac{h}{\lambda_o\sqrt{\varepsilon_r}} \le 0.045$$

$$A = 200 \quad For \quad 0.045 \le \frac{h}{\lambda_o\sqrt{\varepsilon_r}} \le 0.075$$

$$A = 220 \quad For \quad \frac{h}{\lambda_o\sqrt{\varepsilon_r}} \ge 0.075$$

Where h is the substrate thickness, λ_o is the wavelength in the substrate, εr is the dielectric constant of substrate, W, L is the width and length of patch dimension.

4. DESIGN RECTANGULAR PATCH ANTENNA

The resonant frequency of the antenna must be selected properly.

The WIFI applications use the frequency range from (2-3 GHz).

(f_o) selected for this design is (2.4 GHz).

The dielectric material selected

For the design is droid which has a dielectric constant of (εr = 4.4).

The height of the dielectric substrate is selected as h = 6 mm.

The essential parameters for the design are:

f_o = 2.4 GHz, εr = 4.4 (FR4 material), loss tangent = 0.0005 and h = 6 mm.

The transmission line model will be used to design the antenna.

4.1 Calculation of the width (W)

The width of the equation (1) gives at f_o= 2.4 GHz, εr = 4.4, W= 38 mm.

4.2 Calculation of effective dielectric constant (εeff)

Equation (2) gives the effective dielectric constant as: For εr = 4.4 and f_o = 2.4 GHz, it gives: εeff = 3.7.

4.3 Calculation of the length extension (ΔL)

Equation (3) gives the length extension as:

For εeff = 3.7, f_o = 2.4 GHz, W = 38 mm and h = 6 mm it gives: ΔL= 2.44mm.

4.4 Calculation of the effective length

(Leff): Equation (4) gives the effective length as:

For εeff = 3.7 and f_o = 2.4GHz it gives: Leff = 32.5mm.

4.5 Calculation of actual length of patch (L)

The actual length is obtained by equation (5) as:

L = 27.6 mm.

4.6 Calculation of ground plane dimensions (Lg and Wg) by [14] would be given as

For L = 27.6 mm, W = 38 mm and h = 6 mm

Lg = L + 6h ---------- (9) then

Lg = 63.6 mm.

Wg = W + 6h --------- (10) then

Wg = 74 mm.

4.7 Determination of feed point location (Xf, Yf)

Using the equation provided in Bahl/Bhartia [15].

Feed point location where the input impedance is nearly 50 ohm is

Yf = W/2 ---------- (11)

Xf = L /(2 √ εeff) ----- -----(12)

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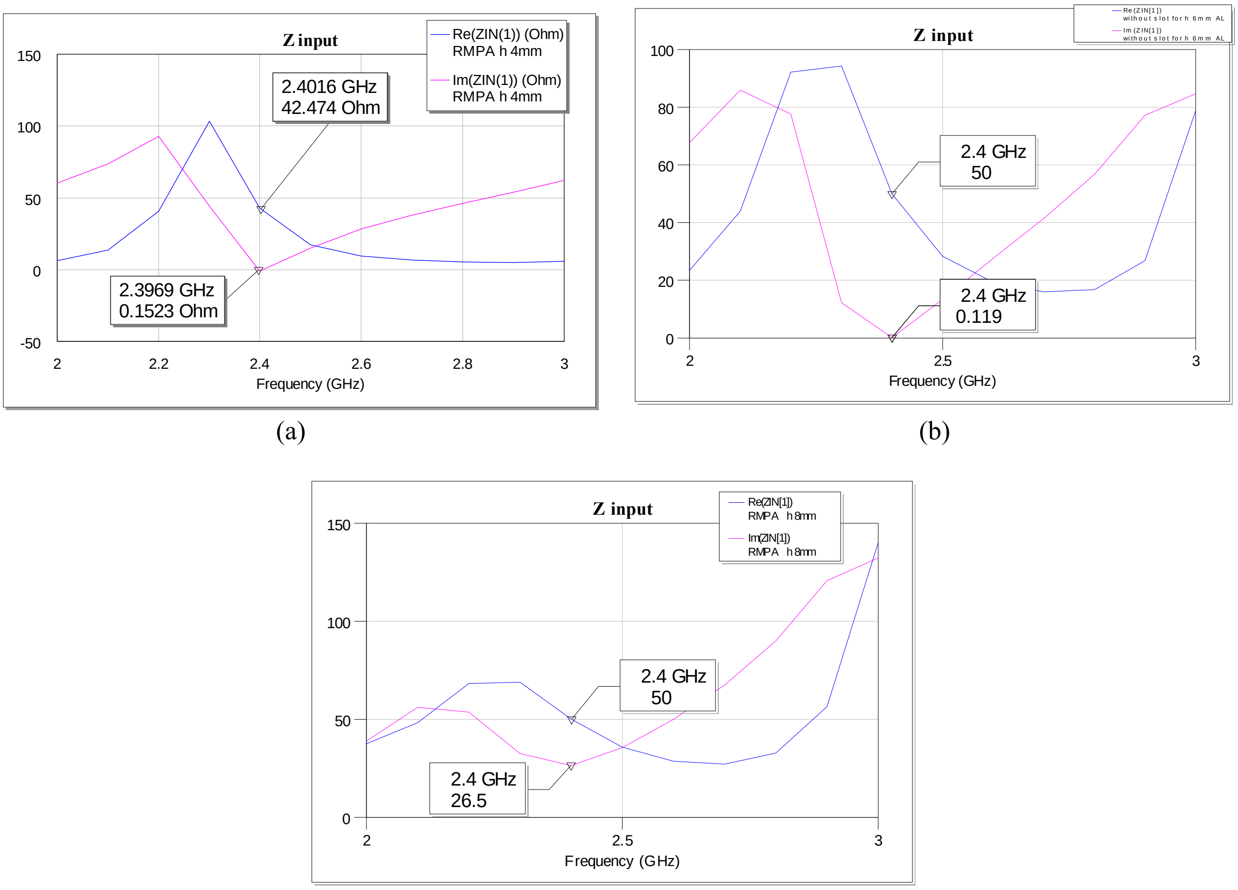
then Yf = 19mm along the width, and Xf = 7.174 mm along the length. When trial and error are used, it was found the best impedance match at feed point location is 2.15625mm of the left edge of the patch, the distance is 11.875mm is of the upper of the length patch, at an input impedance of (50 + j 0.119) ohms.

The software used to model and simulate the MPA is the Microwave Office 2000 package.

The number of divisions is 128 divisions X cell size = 0.43125mm and Y cell size = 0.59375mm.

The top dielectric layer of the enclosure is set to have the properties of air with thickness = 10mm.

5. SIMULATION RESULTS



(a) (b) (c)

Figure-2. The input impedance of the antenna with different thickness (4, 6 and 8mm).

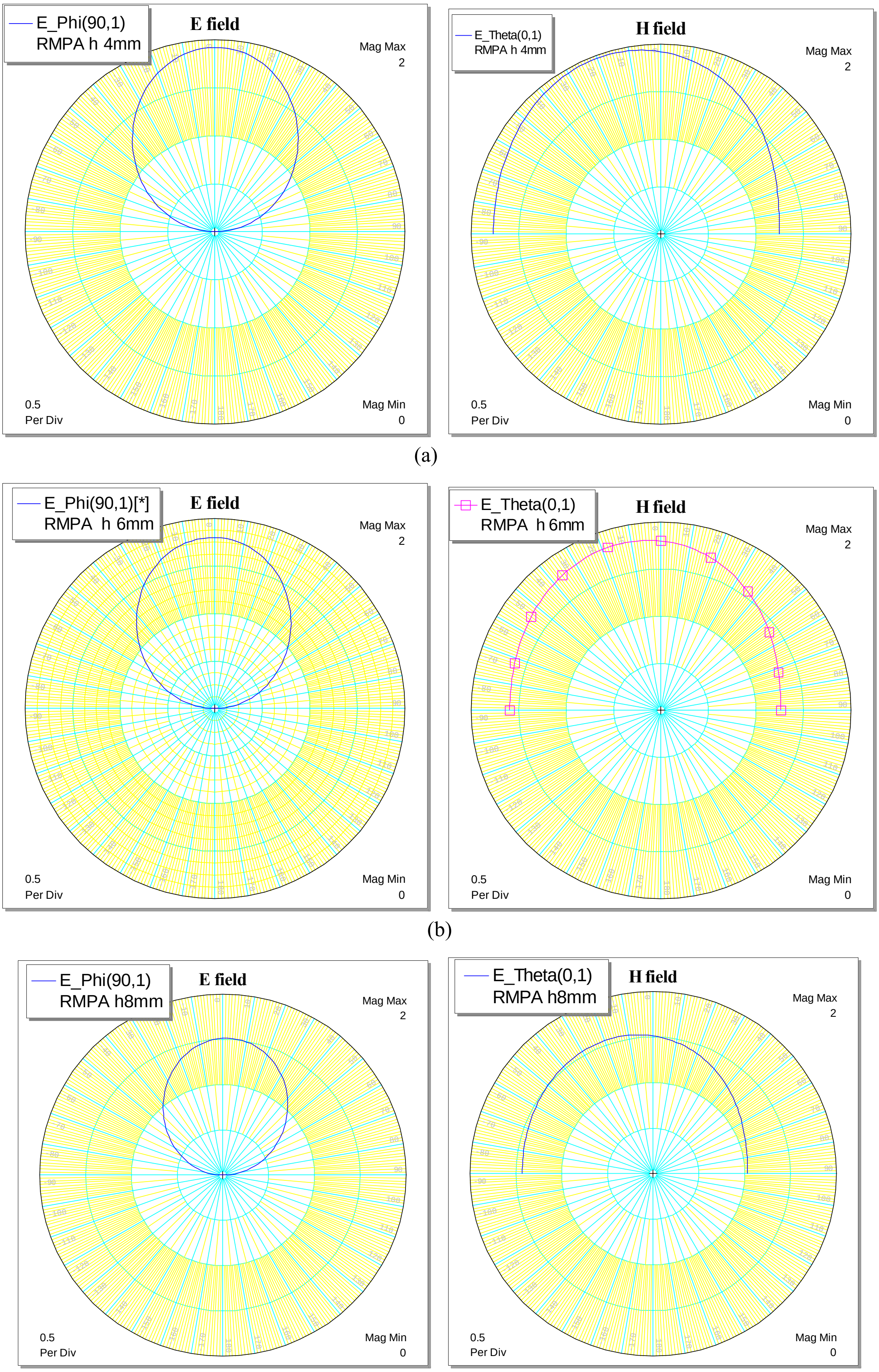


Figure-3. The radiation pattern E-plane, H-plane of the antenna with different dielectric thickness (4, 6 and 8) mm.

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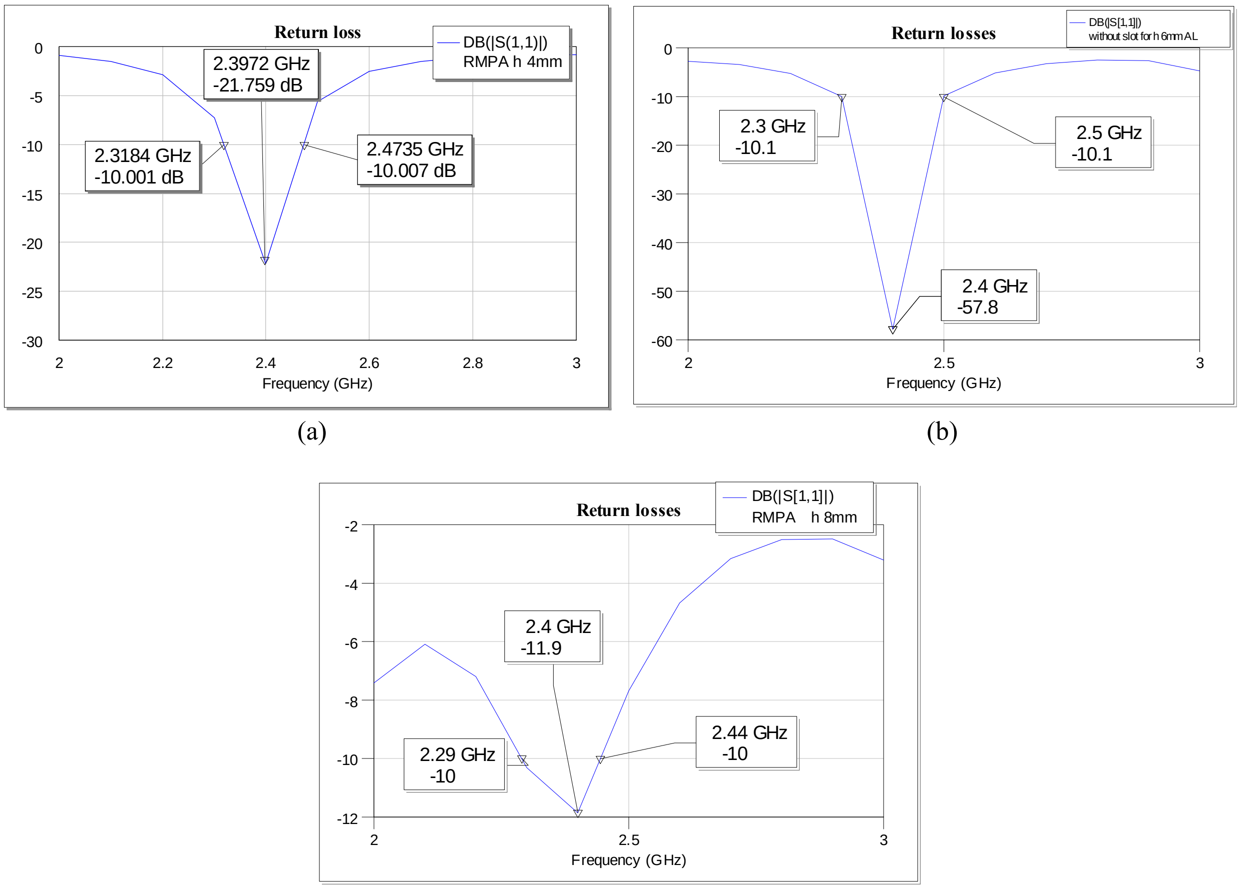

(a) (b)

(c)

Figure-4. The return losses of the antenna with different thickness (4mm, 6mm and 8mm).

The bandwidth can be calculated from the return losses (RL) plot.

With Figure-4a, the simulated impedance bandwidth of (155.1 MHz 6.46 %) from (2.3184) GHz to (2.4735) GHz is achieved at (-10dB) return losses (VSWR $\leq$ 2).

With Figure-4b, the simulated impedance bandwidth of (200MHz 8.33 %) from (2.3) GHz to (2.5) GHz is achieved at – (10dB) return losses (VSWR $\leq$ 2).

With Figure-4c, the simulated impedance bandwidth of (150MHz 6.25 %) from (2.29) GHz to (2.44) GHz is achieved at (-10dB) return losses (VSWR $\leq$ 2).

Table-1. Effect of the dielectric thickness on antenna performance.

Item	**Dielectric thickness** (h mm)	**Patch specification** (mm)	f_o (GHz)	**Return losses**	**BW** (MHz)	**BW** (%)
1	4	W=38mm ΔL=1.8 εeff = 3.83 L=28.336mm	2.4	-21.759 dB	155.1	6.46 %
2	6	W=38mm ΔL=2.625 εeff = 3.7 L=27.6mm	2.4	-57.8dB	200	8.33 %
3	8	W=38mm ΔL=3.415 εeff = 3.6 L=26.08mm	2.4	-11.9dB	150	6.25 %

From Table-1 it can be noticed that as the thickness of the substrate increases the bandwidth increases also.

6. CONCLUSIONS

It appears that from the present work, the possibility of using MW-office package for determine the proper location of a proper feed.

For substrate thickness (4mm) the first design antenna had a (155.1) MHz bandwidth (6.46 % of central frequency). Whereas when the thickness was used (6mm), the bandwidth increased to be (200) MHz, which gives a percent of bandwidth to the centre frequency of (8.33%) that means the bandwidth improvement approximately (45) MHz. whereas when the thickness was used (h = 8mm) the bandwidth decreased to be 150MHz.

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