

# Computational Studies on Rectangular Microstrip Patch Antenna

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**Abstract** – In this paper, the computational studies are performed to compute the principle plane patterns of micro strip patch array antenna. The objective of present work is to design the rectangular micro strip patch antenna to achieve good directivity. The principle plane patterns are computed for different dielectric constants by keeping inter element spacing constant. The best possible antenna array is chosen by computing the Directivity for each dielectric constant.

**Keywords** – Micro Strip Patch Antenna, Dielectric Constant, Directivity, Patch Array, Beam Width.

## I. INTRODUCTION

In recent years, great interest was focused on micro strip antennas for their small volumes, low profiles, excellent integration, and ease of installation, low costs and good performance. These antennas are mainly used for airborne, spacecraft and WI-MAX applications. Presently, there are many other government and commercial applications, such as mobile radio and wireless communications that have similar specifications. With the continuous growth of wireless communication service and constant miniaturization of communication equipment, there are higher and higher demands for the volume of antennas, integration and working band. To meet this requirements micro strip patch antennas have been studied and researched extensively over the past many years.

In the literature many researchers investigated on Return losses, Coaxial fed, radiation patterns of patch antenna array at dielectric constants 2.2, 2.4, etc. and at optimized frequencies 2.3 GHz, 2.45 GHz, 2.5 GHz, etc.

Antenna array is used to improve performances such as gain, directivity etc. In the case of patch antenna array, it can be used to scan the beam of an antenna system and perform various other functions which would be difficult with any single element [1]-[10].

In this paper, a generalized equations of both electric and magnetic field for an  $n$  element patch antenna array are derived and principle plane patterns are computed by considering the phase shift between Patch elements. Array equation is valid for any number of elements operating at any frequency.

## II. BASIC CHARACTERISTICS OF MICROSTRIP PATCH ANTENNA

Microstrip patch antenna consists of very thin metallic strip (patch) placed a fraction wavelength above a ground plane. The patch is so designed that its pattern is maximum normal to the patch. For a rectangular patch, the

length  $L$  of the element is usually  $\lambda/3 < L < \lambda/2$ , where  $\lambda$  is wavelength [1]. The patch and the ground plane are separated by a dielectric substrate of height ( $h$ ) as shown in Fig. 1.

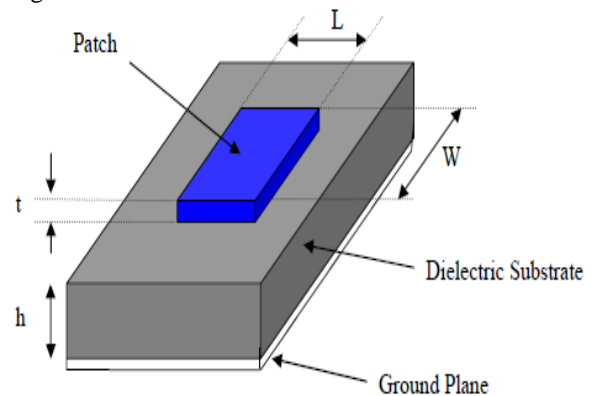


Fig.1. Micro strip patch antenna

There are numerous substrates that can be used for the design of microstrip antennas and their dielectric constants are usually in the range of  $2.2 < \epsilon_r < 12$  [1]. The microstrip line feed is used to feed microstrip patch antenna.

Rectangular patch antenna is approximately a one-half wavelength long section of rectangular Microstrip transmission line [2]. When air is the antenna substrate, the length of the rectangular Microstrip antenna is approximately one-half of a free-space wavelength.

As the antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases. The antenna has become a necessity for many applications in recent wireless communication such as radar, microwave and space communication [2].

## III. DESIGN CONSIDERATIONS FOR RECTANGULAR PATCH ANTENNA

The specifications for the design purpose of the structure are as follows [2].

- Type of antenna: Rectangular Microstrip Patch antenna
- Resonance frequency: 2.45GHz
- free space impedance:  $376.73 \Omega$
- Feeding method: Microstrip Line Feed

The specifications were chosen to design a compact Microstrip patch antenna. The design of the whole structure is performed in the following steps [2]

- Initially, select the desired resonant frequency, thickness and dielectric constant of the substrate

- Obtain width(w) of the patch by inserting
- Obtain Length (L) of the patch after determining.

By using the above considerations of microstrip patch antenna we design the rectangular microstrip patch antenna and we design a flow chart based on usual design procedure for rectangular microstrip patch antenna. [2]

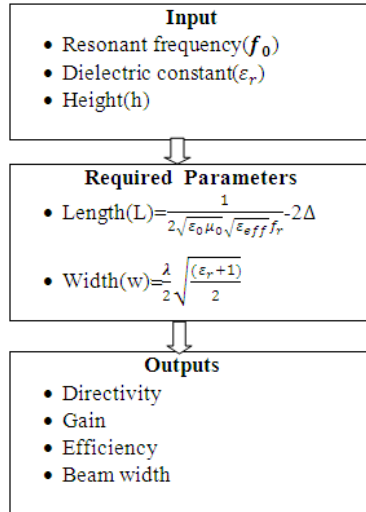


Fig.2. Flow chart based on usual design procedure for rectangular patch antenna

#### IV. EXPRESSIONS OF E-FIELD AND H-FIELD OF PATCH ANTENNA

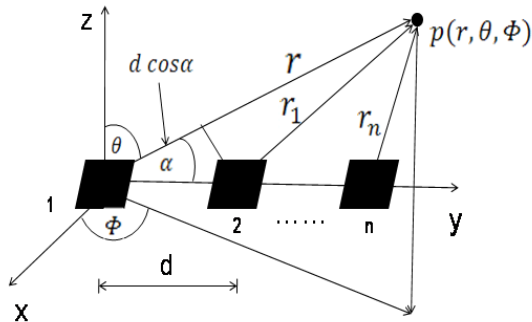


Fig.3. Micro strip patch array

Fig.3 shows a rectangular patch antenna array of n-elements separated from each other by a distance d. The magnetic field intensity and electric field intensity of a single element patch antenna can be expressed as [1]

$$E_{\theta} = \frac{jk I_m h w}{4\pi r} e^{-jkr} \sin(wk \frac{\cos\theta}{2}) \frac{\sin\theta}{kw \frac{\cos\theta}{2}} \quad (1)$$

$$H_{\theta} = \frac{jk I_m h w}{4\eta_0 \pi r} e^{-jkr} \sin(wk \frac{\cos\theta}{2}) \frac{\sin\theta}{kw \frac{\cos\theta}{2}} \quad (2)$$

Where,

k= phase constant =  $2\pi/\lambda$  and  
 $\eta_0$  is the intrinsic impedance

In the array the total field of array can be obtained by multiplying the field of single element with the array factor (AF).

Total field of the array = Field of single element  $\times$  Array factor

For n element patch array the electric field intensity can be expressed as [1]

Assuming,  $\theta_1 = \theta_2 = \theta$

$$E_{\theta} = A \left\{ \frac{e^{-jkr}}{r} + \frac{e^{-j(kr_1-\beta)}}{r_1} + \frac{e^{-j(kr_2-2\beta)}}{r_2} + \dots + \frac{e^{-j(kr_n-(n-1)\beta)}}{r_n} \right\} \quad (3)$$

$$\text{Where } A = \frac{jk I_m h w}{4\pi r} \sin(wk \frac{\cos\theta}{2}) \frac{\sin\theta}{kw \frac{\cos\theta}{2}}$$

Finally for the E-plane, the total field intensity of rectangular patch array is

$$E_{\theta} = A \frac{e^{-jkr}}{r} \times e^{j(n-1)\psi/2} \frac{\sin(n\psi/2)}{\sin(\psi/2)} \quad (4)$$

Where,

$\frac{\sin(n\psi/2)}{\sin(\psi/2)}$  is Array factor

And  $\psi = k d \sin\theta \sin\phi + P$

P is the total phase shift between two patch elements.

Similarly for H-plane, total field intensity of rectangular patch array is

We know

$$H_{\theta} = E_{\theta} / \eta_0$$

so

$$H_{\theta} = \left\{ A \frac{e^{-jkr}}{r} \times e^{j(n-1)\psi/2} \frac{\sin(n\psi/2)}{\sin(\psi/2)} \right\} / \eta_0$$

Therefore the total field intensity of patch array for H-plane is

$$H_{\theta} = \frac{A}{\eta_0} \frac{e^{-jkr}}{r} \times e^{j(n-1)\psi/2} \frac{\sin(n\psi/2)}{\sin(\psi/2)} \quad (5)$$

#### V. RESULTS AND CONCLUSION

The principle plane patterns for single element patch antenna operating at 2.45 GHz are plotted by using (1) and (2). Here the Directivity is computed by using formula.

$$D = \frac{4(kw)^2}{\pi \eta_0 G_r} \quad (6)$$

Where,

$G_r$  is radiation conductance

$$G_r = \frac{w\pi}{\eta\lambda} \left[ 1 - \frac{(kh)^2}{24} \right] \quad (7)$$

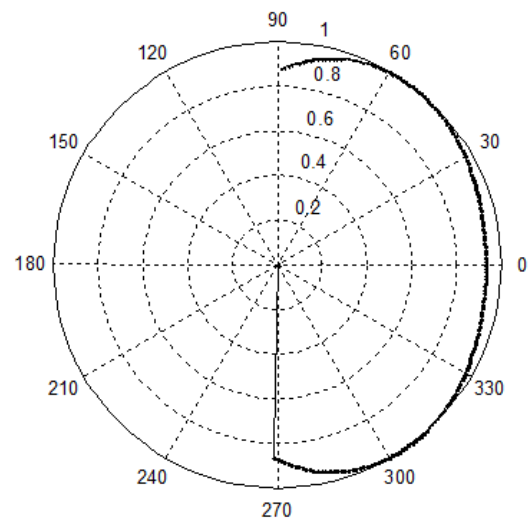


Fig.4. E-plane radiation pattern for single element Patch antenna at  $\epsilon_r = 2.32$  (Duroid)

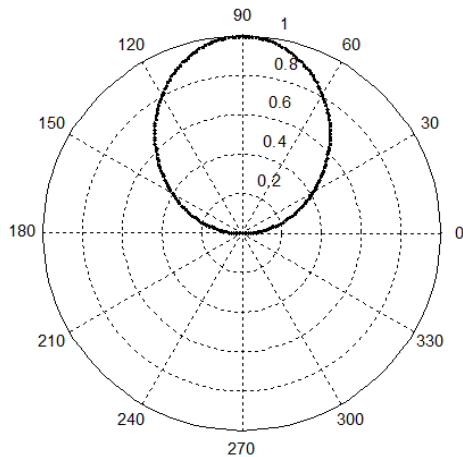


Fig.5. H-plane radiation pattern for single element Patch antenna at  $\epsilon_r= 2.32$  (Duroid)

Hear for the single element microstrip patch antenna the obtained Directivity is 6.1374db

The principle plane patterns for n element patch antenna array at different dielectric constants operating at 2.45 GHz are plotted by using (4) and (5) and beam width is computed from those patterns. For this patch antenna array the directivity is computed by multiplying directivity of single element with array factor (AF).

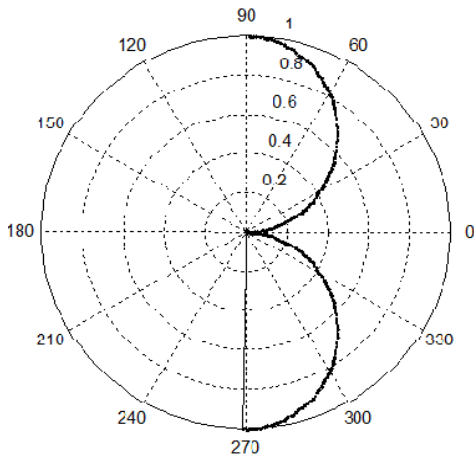


Fig.6. E-plane radiation pattern for 2-element Patch antenna at  $\epsilon_r= 2.32$  (Duroid)

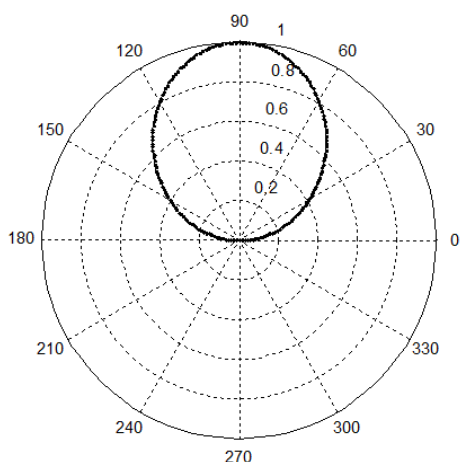


Fig.7. H-plane radiation pattern for 2-element Patch antenna at  $\epsilon_r= 2.32$  (Duroid)

Table 1 shows the variation of Beam width and Directivity of rectangular patch antenna array for the E-plane and H-plane patterns at different dielectric substrate values by keeping inter element spacing constant  $d=0.075\lambda$ , with the number of elements  $n=2$  and at operating frequency  $f=2.45\text{GHz}$

Table 1: Beam width and Directivity for different Dielectric constants

Dielectric constant ( $\epsilon_r$ )	2.1	2.2	2.32	2.4	2.6
Beam width for the E-Plane (deg)	51.69	51.890	52.007	52.257	52.59
Beam width for the H-Plane(deg)	12.85	12.651	12.474	12.273	11.92
Directivity of principle Plane patterns in db	51.69	51.889	52.005	52.256	52.59

From the results presented in Table.1 it was observed that the patch array has good directivity with low value of dielectric constant. Directivity is slightly lower for high value of dielectric constant presented in Table.1.

Even though the directivity is high for  $\epsilon_r=2.1$ , but, based on dielectric losses and surface wave losses, the dielectric substrate with duroid ( $\epsilon_r= 2.32$ ) is best suited for design of Microstrip patch array.

The microstrip patch with duroid as the substrate may be useful for wireless communication applications.

Table.2 Shows the description of symbols in rectangular patch antenna array which are shown in fig. 3

Table 2: Description of symbols in patch antenna Array

S. No	symbol	Meaning	Units if any
1	r	Distance from origin to the object in space(p)	Meters
2	$\theta$	The angle between line drawn to object(p) from origin to z-axis	Degrees
3	$\phi$	The angle between the line drawn from horizontal projection of object (p) to x-axis	Degrees
4	$\psi$ (or) $\alpha$	The angle between the line drawn to object(p) from origin to y-axis	Degrees
5	d	Inter element spacing constant	Meters
6	h	Hight of dielectric substrate.	Meters
7	L	Length of Microstrip Patch	Meters
8	W	Width of Microstrip Patch	Meters
9	t	Hight of Microstrip Patch	Meters
10	$\epsilon_r$	Dielectric constant	No units
11	$\lambda$	Operating wave length	Meters
12	f	Operating frequency	GHz

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