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Performance Analysis of Rectangular Patch Antenna with Dielectric Constants

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***Abstract:** The developments in communication systems, patch antennas play a very significant role in today's world of communication systems. The most commonly used micro strip patch antennas are Rectangular patch antennas.*

The rectangular micro strip patch antenna parameters are analyzed for S-band frequency which is used for wireless communications(2.0-2.5GHz). In this design, performance parameters like V.S.W.R, Returnloss, are simulated and radiation patterns are observed.

Rectangular patch antenna is designed with uniform and non-uniform linear arrays. The uniform and non-uniform arrays are designed with Dolph-Tschebycheff.

***Keywords :** Rectangular micro strip patch antenna, uniform array and Dolph-Tschebycheff .*

I. INTRODUCTION

Radiating element of rectangular patch antenna on one side of a dielectric substrate which has a ground plane on the other side of the antenna are shown in Fig.1.

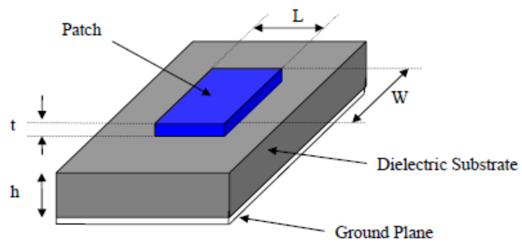
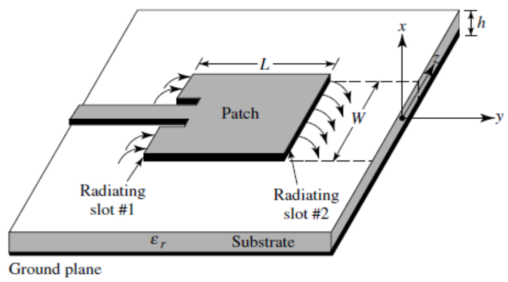
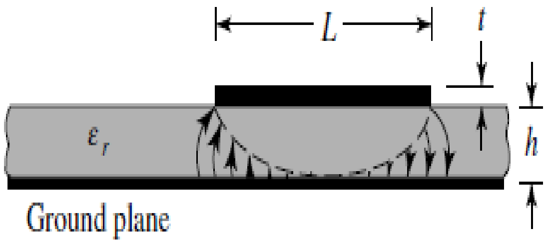


Fig.1. Rectangular antenna

The patch is made of conducting material such as copper or gold and can be found in various shapes. The radiating element & feed lines are fabricated using a process of photo etching which uses a photo resist and etchants to corrosively machine away selected areas on the dielectric substrate. Structure and side view of the rectangular microstrip patch antenna as shown in Fig. 2.



(a)Structure of Microstrip antenna



(b) side view of Rectangular antenna
Fig. 2. structure and side view of antenna

Some of the other common shapes in micro strip antennas n shown in Fig.3.

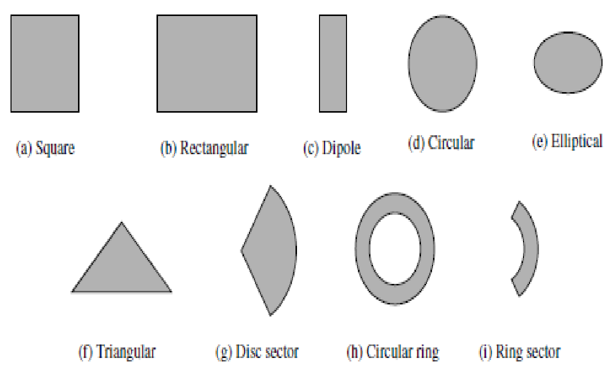


Fig. 3.Diff. shapes of patch

II. RECTANGULAR MICROSTRIP PATCH GEOMETRY

Rectangular microstrip antenna consists of a very thin such that $t << \lambda_0$ (where λ_0 is the free – space wavelength and t is the patch thickness) metallic strip is placed a small fraction of a wavelength, dielectric height h ,is usually $0.003\lambda_0 \leq h \leq 0.05\lambda_0$ above a ground plane. The L is the length of the patch is usually $0.3333\lambda_0 < L < 0.5\lambda_0$

III. RECTANGULAR PATCH DESIGN EQUATIONS

A. The width of the microstrip patch antenna

$$W = \frac{c}{2 f_r \sqrt{\frac{\varepsilon_r + 1}{2}}}$$

c = The speed of light
W = Patch width
ε_r = Substrate dielectric constant
f_r = Resonant frequency

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B. Effective dielectric constant ε_{reff}

$$\varepsilon_{reff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2} + \left[1 + 12\frac{h}{W}\right]^{1/2}$$

C. The effective length L_{eff}

$$L_{eff} = L + 2\Delta L$$

Rectangular patch length

$$L_{eff} = L + 2\Delta L$$

D. The resonance frequency:

$$f_r = \frac{C}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}}$$

E. The radiated power:

$$p_{rad} = \frac{|V_0|^2}{2\pi\eta_0}\int_0^{\pi}\left[\frac{\sin\left[\frac{k_0W}{2}\cos\theta\right]}{\cos\theta}\right]^2 \sin^3\theta d\theta$$

Rectangular patch antenna, the *x-y* plane (θ = 90◦ , 0◦ ≤ φ ≤ 90◦ and 270◦ ≤ φ ≤ 360◦) is the principal *E*-plane. The radiated fields

$$E_\Phi^t = \frac{+jk_0WV_0e^{-jk_0r}}{\Pi r}\left\{\frac{\sin(\frac{k_0h}{2}.\cos\phi)}{\frac{k_0h}{2}\cos\phi}\right\}\cos(\frac{k_0Le}{2}\sin\phi)$$

E- plane(θ =90°,0°≤ ϕ ≤90° and 270°≤ ϕ ≤360°)

$$E_\theta^t = +j\frac{k_0WV_0e^{-jk_0r}}{\Pi r}\left\{\sin\theta\frac{\sin(\frac{k_0h}{2}\sin\theta)}{\frac{k_0h}{2}\sin\theta}\frac{\sin(\frac{k_0W}{2}\cos\theta)}{\frac{k_0W}{2}\cos\theta}\right\}$$

H-plane(ϕ =0°, 0°≤ θ ≤180°)

F. Directivity of a single slot given as

$$D_0 = \left(\frac{2\pi W}{\lambda_0}\right)^2\frac{1}{I_1}$$

Where

$$I_1 = \int_0^{\Pi}\left[\frac{\sin\left[\frac{k_0W}{2}\cos\theta\right]}{\cos\theta}\right]^2 \sin^3\theta d\theta$$

G. Reflection Coefficient |Γ|

Reflection coefficient given by

$$\Gamma = \frac{V_0^+}{V_0^-} = \left(\frac{Z_L - Z_0}{Z_L + Z_0}\right)$$

V_0^+ incident voltage

V_0 voltage of reflection

Where |Γ| is the reflection coefficient

H. Voltage Standing Wave Ratio(VSWR)

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{(1+|\Gamma|)}{(1-|\Gamma|)}$$

VSWR ranges from 1 to ∞.

I. Return Loss

$$RL = -20\log|\Gamma|(dB)$$

Where |Γ| is the reflection coefficient

IV. RECTANGULAR MICROSTRIP PATCH ARRAY

This paper presenting two different arrays .

A.The Arrayfactor of an N-element linear array of isotropic sources is

$$AF = 1 + e^{ikd\cos\theta} + e^{ik2d\cos\theta} + ...e^{jk(N-1)d\cos\theta}$$

$$= \sum_{m=0}^{N-1} e^{ikmd\cos\theta} = \sum_{m=0}^{N-1} e^{jkm\frac{d}{N-1}\cos\theta}$$

For the rectangular array antenna, the principal E-plane in x-y is given by

$$E_a(\phi) = E(\phi)\times AF$$

	Dielectric Constant=9.8 (Alumina)	Dielectric Constant=2.23 (Duroid)
Length(mm)	9.96	41.84
Width(mm)	26.89	49.12
Efficiency	0.9996	0.9998
Gain	14.31	20.14
Directivity(dB)	5.3306	7.3496
Characteristic Impedance	71.9	92.3
E-PLANE HPBW (degrees)	180	94
H-PLANE HPBW degrees)	86	78

$$= \frac{\sin\left(\frac{k_0h}{2}\cos\phi\right)}{\frac{k_0h}{2}\cos\phi}\sin\left(\frac{k_0L}{2}\cos\phi\right)\times\frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)}$$

B. Dolph-Tschebyscheff Array.

For a broadside array(β =0), P=2M(even)

$$(AF)_e = 2\sum_{n-1}^{M} a_n\cos[(\frac{2n-1}{2})\frac{\pi d}{\lambda}\cos\theta\ ]$$

$$u = \frac{\pi d}{\lambda}\cos\theta$$

V. RESULTS AND CONCLUSIONS:

Rectangular micro strip patch antenna output parameters are designed using S-band frequency which is used for Wi-Fi applications. The sizing of the antenna are the width(W) ,Length (L) and the performance parameters of the antenna are shown in Table1, observed that with ε_r =2.23 ,the size of

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the antenna(L= 41.84mm, W= 49.12mm) increased. Directivity of the antenna is very high= 7.35 dB. With the 9.8(Alumina),the sizeof the antenna (L=9.96mm, W=26.89mm) reduced, and the Directivity of the antenna is low= 5.33dB .

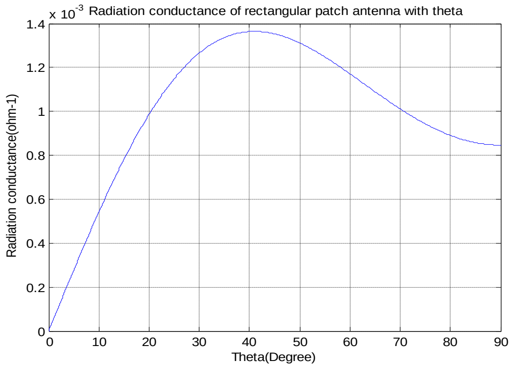

Fig. 4. Variation of Radiation in the rectangular microstrip patch with Theta.

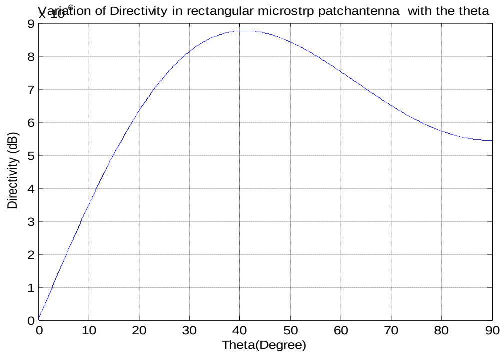

Fig. 5. Variation of Directivity in the rectangular microstrip patch with Theta.

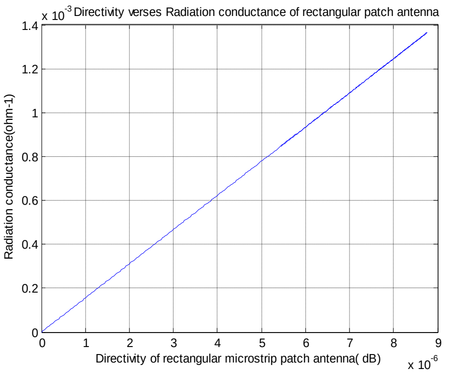

Fig. 6. Variation of Radiation Conductance with Directivity of rectangular patch

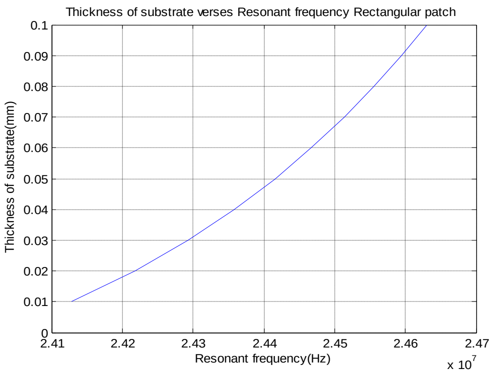

Fig. 7. Plot of variation of Thickness of substrate with Resonant frequency of rectangular microstrip patch.

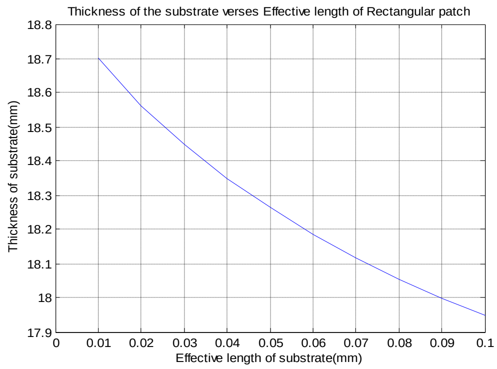

Fig. 8. Plot of variation of Thickness of substrate with Effective length.

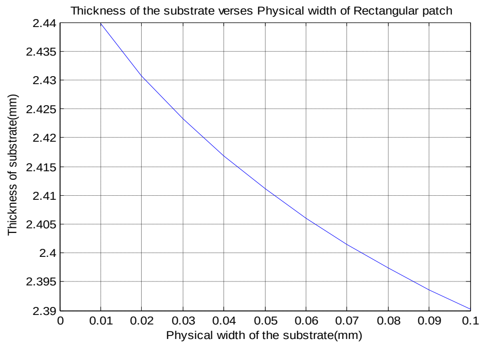

Fig. 9. Plot of variation of Thickness of substrate with Physical width of the substrate for rectangular microstrip patch.

Performance parameters of rectangular patch antenna are VSWR and Returnloss, are simulated.

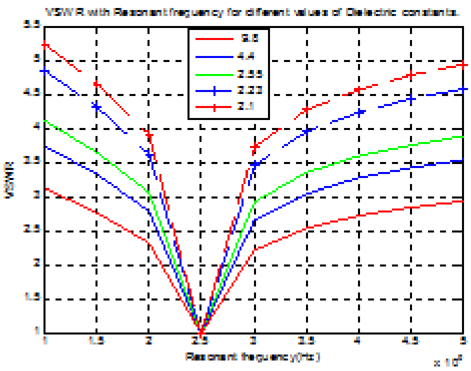

Fig. 10..Variation of VSWRof rectangular microstrip patch with respect to frequency.

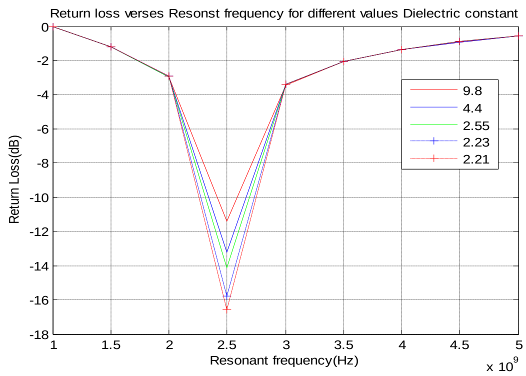

Fig .11. Variation of Return losses of rectangular microstrip patch at 2.5 GHz.

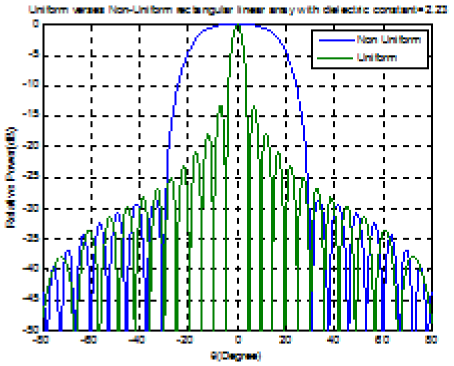

Fig. 12. 20 element rectangular microstrip linear array with Dieleectric constant (ε_r)= 2.23.

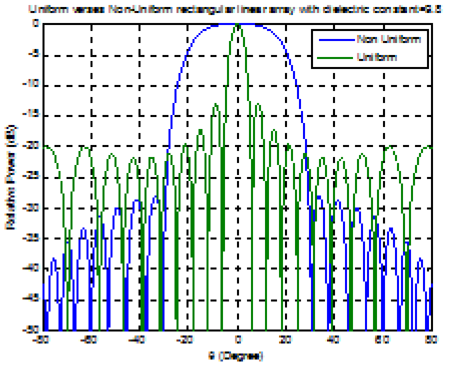

Fig. 13. 20 element rectangular microstrip linear array with ε_r= 9.8.

Table.2.Comparison between uniform & non uniform rectangular microstrip array antenna Side Lobe Level (SLL) with different values of substrate dielectric constant(ε_r) values.

Dielectric constant (ε_r)	Uniform rectangular linear array		Non uniform rectangular linear array	
	HPBW (Deg.	*PSLL (dB)*	*HPBW (Deg.*	*PSLL (dB)*
1	4.22	-13.36	35.1	-30
2.23	4.42	-13.28	35.8	-28.48
4.4	5.02	-13.20	36.24	-28.2
9.8	5.30	-13.07	36.42	-28.06

Table 2. shows the Comparison between uniform & non uniform rectangular microstrip array antenna Peak Sidelobe Level (SLL) with different values of substrate dielectric constant(ε_r).

From all the simulated results from the table 2, the rectangular micro strip antenna with non uniform array, with lower values of ε_r is preferred to get, reduced Peak Sidelobe Level, HPBW, FNBW, good voltage standing ratio and good Returnlosses, this designed rectangular array is good choice to used in Wi-Fi Modems.

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