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RESEARCH ARTICLE

RECTANGULAR MICROSTRIP PATCH ANTENNA USING COAXIAL PROBE FEEDING TECHNIQUE ON DIFFERENT DIELECTRIC CONSTANT FOR INSTRUMENTATION AND RECEIVERS

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ABSTRACT

In this Paper presents the result for different dielectric constant values and the result is performed by thickness of 2.88mm and resonance frequency of 2GHz where 2.32 (Duroid) are gives the best result. In the recent years the development in communication systems requires the evelopment of low cost, minimal weight, low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. This technological trend has focused much effort into the design of a Microstrip patch antenna. The proposed antenna design on different dielectric constant and analyzed result of all dielectric constant from 1 to 10, when the proposed antenna designs on Duroid substrate with dielectric constant 2.32. At 2GHz verified and tested result on MATLAB are Radiation Efficiency=91.99%, Directivity=5.4dBi, Directive gain=4.98dBi and Half Power Beam Width-H plane=99.6123 degrees.

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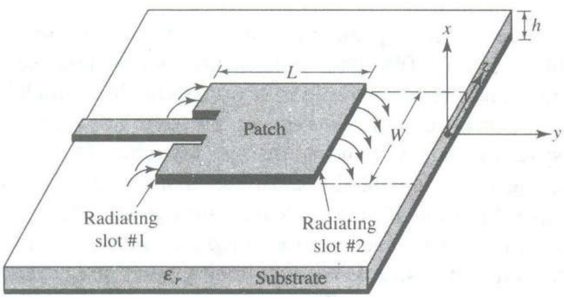
INTRODUCTION

Antenna arrays are normally used in high gain beam scanning shaped beam generation for various applications in instrumentation and in receivers (Tamijani *et al*., 2004). Arrays usually have low gain antenna elements which are arranged in particular geometry in order to meet the above mentioned applications. The antenna elements which are radiating have excitation coefficients and related parameters which are to be studied in any specific applications. Enough number of research papers is there in the study of patch antenna and its arrays. The antenna characterisations are mainly done depending upon the dielectric material on its bandwidth. A simple rectangular patch antenna which exhibits radiation pattern is a smart antenna useful in many applications of mobile communications. Arrays of patch antenna have applications in instrumentation (Chin *et al*., 2005; Lee *et al*., 2006).

Basic Characterization

The micro strip antenna received importance in the year 1970. The idea of micro strip antenna was propagated from the below figure



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$h \square \lambda_0$

$\frac{\lambda_0}{3} \square \; \lambda_0$

$2.2 \square \; \varepsilon_0 \square \; 12$

$Z_i \equiv \sqrt{\frac{\mu}{\varepsilon}} \equiv Z_0 \sqrt{\frac{\mu_0}{\varepsilon_r}}$

$\varepsilon_r \equiv 1, \mu_{r=1}$

$Z_i = Z_0$

$n = \frac{w}{h}$

$Z_c = \frac{Z_0}{n\sqrt{\varepsilon_r}}$

$Z_c = \frac{Z_0}{(n+2)\sqrt{\varepsilon_r}}$

$\lambda = \frac{\lambda_0}{\varepsilon_r}$

$Z = \frac{Z^2{}_0}{4Z_d}$

Z_d

$E_x = E_0 COS\left(\frac{\pi}{L} Y'\right)$

$H_Z = H_0 COS\left(\frac{\pi}{L} Y'\right)$

$Y' = 0t0Y' = L$

$\left(f_r\right)_{010} = \frac{L}{2\sqrt{\mu\varepsilon_0}} = \frac{v_0}{2L\sqrt{f_r}}$

$E_x = E_y$

$H_x = H_y$

$E_0 = JwA_{010}$

$H_0 = \pi\mu A_{010}$

$E_r = E_\theta = 0$

$E_\phi = j\frac{k_{0hw} E_0 e^{-jk_0 r}}{2\pi r}\left[Sin\theta \frac{SinX}{X}\frac{SinZ}{Z}\right]$

$X = \frac{k_0}{2} Sin\theta Cos\phi$

$Z = \frac{k_0}{2} Cos\ \theta$

$E_\phi = +j\frac{v_0 e^{-jk_0 r}}{\pi r}$

$\left[Sin\theta \frac{Sin\left(\frac{k_0 w}{2}\cos\theta\right)}{\cos\theta}\right]$

$V_0 = hE_0$

L_{eff}

$\left(AF\right)_Y = 2COS\frac{k_0 L_{eff}}{2} Sin\theta\ Cos\phi$

$E - plane\left(\theta = 90°, 00 \le \phi \le 90°\ and\ 270° \le \phi \le 360°\right)$

$E_\phi{}' = +j\frac{k_{ow} V_0 e^{-jk_0 r}}{\pi r}\left[\frac{\sin\left(\frac{k_0 h}{2}\cos\phi\right)}{\frac{k_0 h}{2}\cos\phi}\right]\cos\left(\frac{k_0 L_{eff}}{2}\sin\phi\right)$

$H - plane\left(\phi = 0°, 0° \le \theta \le 180°\right)$

It consists of a thin layer t < < λ_0 where λ_0 is free space wavelength of metallic strip with t as the thickness. The metallic strip placed as a small fraction of wavelength above the ground plane. The micro strip patch is designed so that its pattern is maximum in the direction normal to the patch i.e as a broadside radiation (Lee *et al*., 2005; Lee *et al*., 2006; Chang and Hsieh, 2004). This is achieved by choosing the mode of excitation below the patch. The end fine radiation is produced by judicious mode selection. For any rectangular patch the length l of the element is usually $\frac{\lambda_0}{3}$ □ λ_0 the strip and the ground plane are separated by dielectric strip as shown in above figure.

There are numerous substrates that can be used for design of micro strip antennas and their dielectric constants which are in the range of 2.2 □ ε_0 □ 12

The one of the most desirable for good antenna performance are thick substrate whose dielectric constants in the lower end of the range which provides better efficiency and larger bandwidth. But at an expense of larger element thin substrates with higher dielectric constants are desirable for microwave circuitry, as they require tightly bound fields to minimise undesired radiations and coupling. In respect of smaller element sizes, greater losses are associated with relatively smaller bandwidths. Since micro strip antennas often integrated with other microwave circuitry, a compromise has to be reached between good antenna performance and circuit design (Workshop on phased arrays Radar techniques, 1995).

The patch antenna acts as resonant $\frac{\lambda}{2}$ parallel plate micro strip transmission line with characteristic impedance equal to reciprocal of the number of ‘ n ‘ parallel field cells. The field cells have characteristic impedance which is equal to intrinsic impedance of the medium i.e $Z_i \equiv \sqrt{\frac{\mu}{\varepsilon}} \equiv Z_0\sqrt{\frac{\mu_0}{\varepsilon_r}}$ For air medium, $\varepsilon_r \equiv 1, \mu_{r=1}$ and $Z_i = Z_0$ i.e output impedance calculated from the software =135Ω

A view in patch shows that the cross section has parallel field cells of the transmission line given by $n = \frac{w}{h}$ and from this calculation by a selected value of h, the micro strip characteristic impedance is evaluated i.e $Z_c = \frac{Z_0}{n\sqrt{\varepsilon_r}}$

This relation used for calculating characteristic impedance does not include the fringing of the field at the edges. Hence two cells are to be added on either side of the patch to overcome the fringing effect of the field. Hence the modified relation of the characteristic impedance is calculated by the formula (Pal, 1995)

$$Z_c = \frac{Z_0}{(n+2)\sqrt{\varepsilon_r}}$$

The resonating length l of the patch is critical and is a couple of prevent less than $\frac{\lambda}{2}$ where λ is the wavelength in dielectric i.e $\lambda = \frac{\lambda_0}{\varepsilon_r}$,this can be used to determine the impedance for the dielectric substrate ε_r=1 and modified impedance is given by

$$Z = \frac{Z^2{}_0}{4Z_d}$$

Where Z_d is impedance of complimentary dipole for a patch of a given λ and $\frac{z}{100}$ wide (Edward A. Wolff and Roger Kaul, 2011). The complimentary dipole impedance is calculated from the formula which is about 50Ω .This is suitable for watching the impedance of the transmission line carrying the power to the patch antenna for maximum power feeding (Holzhemer and Miles, 1985).

EXPERIMENTAL

RADIATION CHARACTERISTICS

A micro strip antenna can be represented by two radiating slots along the length of the patch, each of width w and height h. The two slots are separated by the length of the patch are known as radiating slots. The slots separated by impedance parallel plates acts as a transformer with transmission length equal to $\frac{\lambda}{2}$ where λ is guide wavelengths. The two slots have opposite polarization. The two slots form two element arrays with a spacing of $\frac{\lambda}{2}$ between the elements. It will show here in a direction perpendicular to the ground plane. The components of fields add in phase giving maximum radiation normal to the patch and it is broadside antenna. Assuming the dominant mode $T_{01\ 0}$mode, electric and magnetic field components are given by

$$E_x = E_0 COS\left(\frac{\pi}{L}Y'\right)$$

$$H_Z = H_0 COS\left(\frac{\pi}{L}Y'\right) \quad \text{With} \quad E_x = E_y$$

And $H_x = H_y$

Where $E_0 = JwA_{010}$

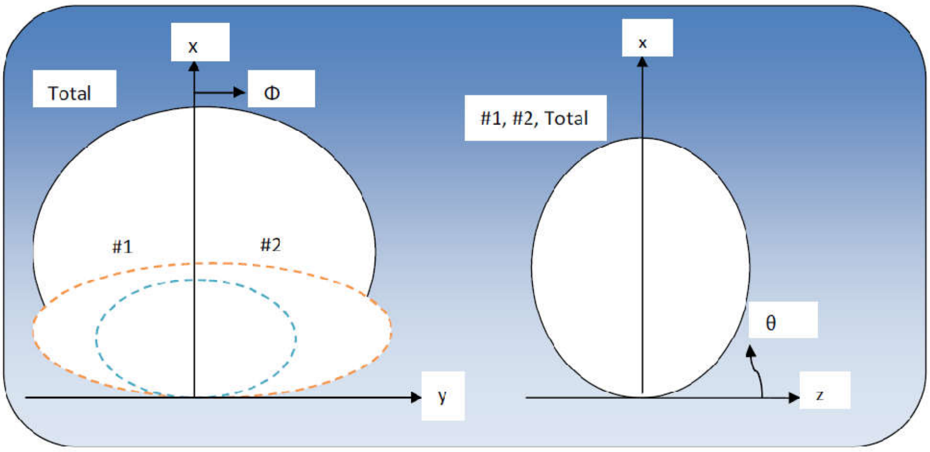
And $H_0 = \pi\mu A_{010}$

The electric field spectrum within the substrate and between the radiating slots and the ground plane is sketched in below figure, where Y' is the field within the cavity $Y' = 0t0Y' = L$

RESULTS AND DISCUSSION

By Computation Method

Y_1	E_x	Hz
10.100000	-0.997939	0.064173
10.200001	-0.999441	0.033437
10.300001	-0.999996	0.002670
10.400002	-0.999605	-0.028100
10.500002	-0.998267	-0.058844
10.600002	-0.995984	-0.089532
10.700003	-0.992758	-0.120135
10.800003	-0.988591	-0.150624
10.900003	-0.983489	-0.180971
11.000004	-0.977455	-0.211146
11.100004	-0.970495	-0.241121
11.200005	-0.962616	-0.270868
11.300005	-0.953826	-0.300359
11.400005	-0.944133	-0.329565
11.500006	-0.933546	-0.358459
11.600006	-0.922074	-0.387013
11.700006	-0.909729	-0.415202
11.800007	-0.896523	-0.442996
11.900007	-0.882468	-0.470372
12.000008	-0.867578	-0.497302
12.100008	-0.851865	-0.523761
12.200008	-0.835346	-0.549724



Mode frequency, $(f_r)_{010} = \frac{L}{2\sqrt{\mu\varepsilon_0}} = \frac{v_0}{2L\sqrt{f_r}}$

Fallowing a produce similar to that used to analyse the aperture, the far zone electric fields radiated by each slot using equivalent current densities is given by

$$E_r = E_\theta = 0$$

$$E_\phi = j\frac{k_{0hw}E_0 e^{-jk_0 r}}{2\pi r}\left[Sin\theta \frac{SinX}{X}\frac{SinZ}{Z}\right]$$

Where $X = \frac{k_0}{2} Sin\theta Cos\phi$

$$Z = \frac{k_0}{2} Cos\,\theta$$

For every small height, it reduces to $E_\phi = +j\frac{v_0 e^{-jk_0 r}}{\pi r}\left[Sin\theta \frac{Sin\left(\frac{k_0 w}{2}\cos\theta\right)}{\cos\theta}\right]$

Where $V_0 = hE_0$

The array factor for two elements of same magnitude and phase separated by distance L_{eff} along Y direction is given by

$$(AF)_Y = 2COS\frac{k_0 L_{eff}}{2} Sin\theta\, Cos\phi$$

Where L_{eff} is effective length and the total electric field for the two slots is given by

$$E - plane\left(\theta = 90°, 00 \le \phi \le 90°\ and\ 270° \le \phi \le 360°\right)$$

For the micro strip antenna, the x-y plane **(θ= 90^0 ,0^{0-} ≤ϕ≤90^0 and 270^0≤ϕ≤360^0)** is the principal E- plane. For this plane, the expressions for the radiated fields reduces to

$$E_\phi{}' = +j\frac{k_{ow}V_0 e^{-jk_0 r}}{\pi r}\left[\frac{\sin\left(\frac{k_0 h}{2}\cos\phi\right)}{\frac{k_0 h}{2}\cos\phi}\right]\cos\left(\frac{k_0 L_{eff}}{2}\sin\phi\right)$$

$$H - plane\left(\phi = 0°, 0° \le \theta \le 180°\right)$$

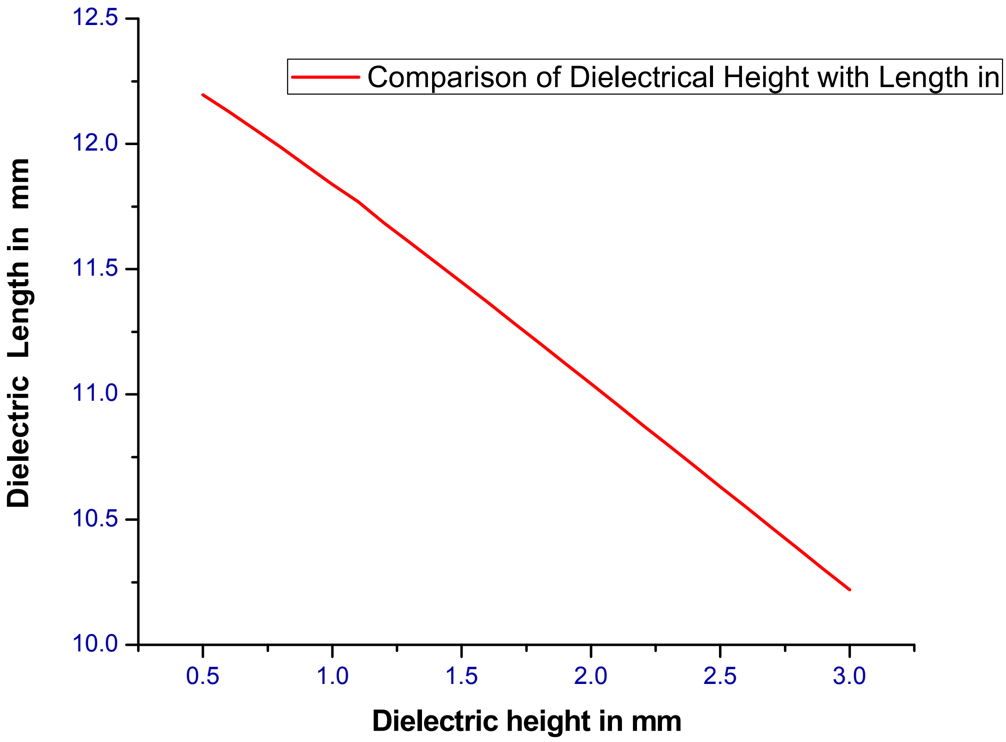
The principal H-plane of the micro strip antenna is the x-z plane $\left(\phi = 0°, 0° \le \theta \le 180°\right)$ and the expressions for the radiated fields reduces to

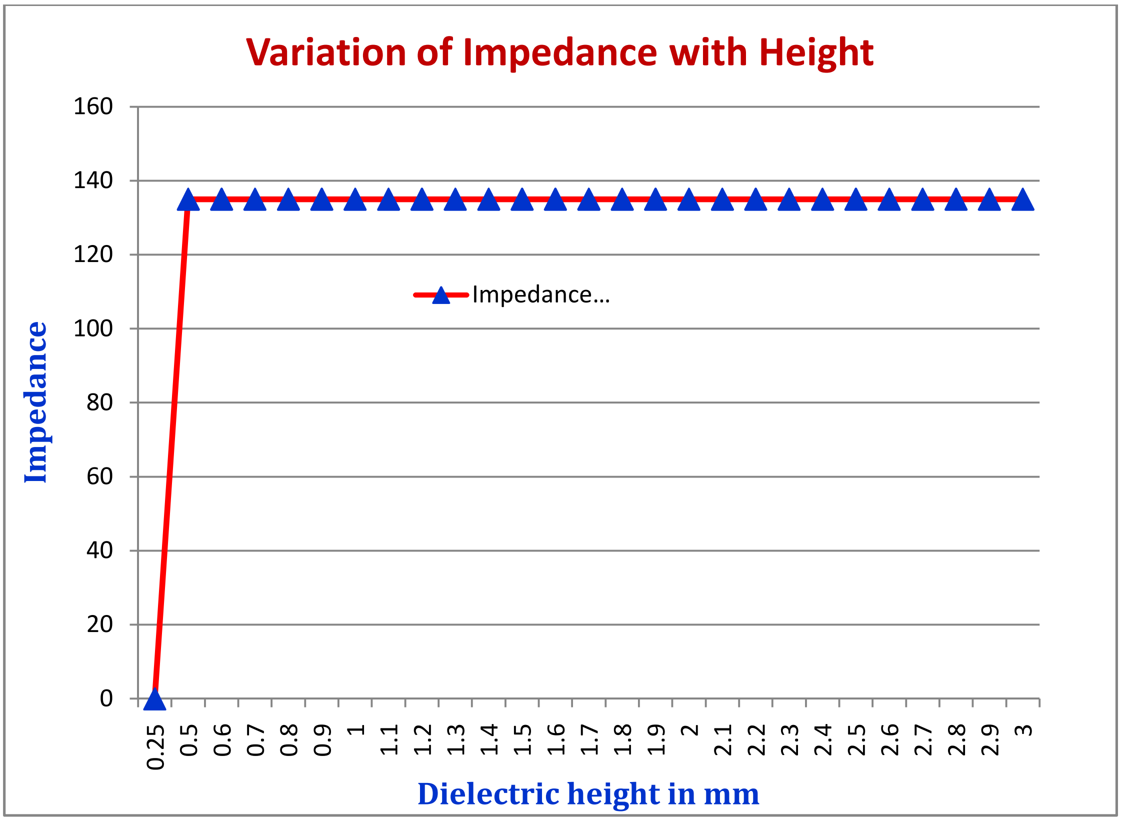
$$E'_\phi = +j\frac{k_{0w}V_0 e^{-jk_0 r}}{\pi r}\left[\frac{\sin\left(\frac{k_{0h}}{2}\cos\theta\right)}{\frac{k_0 h}{2}\sin\theta}\ \frac{\sin\left(\frac{k_0 w}{2}\cos\theta\right)}{\frac{k_0 w}{2}\cos\theta}\right]$$

To illustrate modelling of the micro strip antenna using cavity model in the principal E and H plane patterns can be plotted using the respective expressions.

Impedance calculation

Resonant Frequency(GHz)	Dielectric constant (ε_r)	Dielectric height(h) mm	Length (L) mm	Width (w)mm	Input Impedance (ohm)
8.5	2.0	0.5	12.19514	14.430876	135
8.5	2.0	0.6	12.12774	14.430876	135
8.5	2.0	0.7	12.05798	14.430876	135
8.5	2.0	0.8	11.98662	14.430876	135
8.5	2.0	0.9	11.91274	14.430876	135
8.5	2.0	1.0	11. 83779	14.430876	135
8.5	2.0	1.1	11. 76958	14.430876	135
8.5	2.0	1.2	11. 68430	14.430876	135
8.5	2.0	1.3	11. 60609	14.430876	135
8.5	2.0	1.4	11. 52709	14.430876	135
8.5	2.0	1.5	11. 44772	14.430876	135
8.5	2.0	1.6	11. 36718	14.430876	135
8.5	2.0	1.7	11. 28646	14.430876	135
8.5	2.0	1.8	11. 20533	14.430876	135
8.5	2.0	1.9	11. 12388	14.430876	135
8.5	2.0	2.0	11. 04215	14.430876	135
8.5	2.0	2.1	11. 96020	14.430876	135
8.5	2.0	2.2	10. 87809	14.430876	135
8.5	2.0	2.3	10. 79586	14.430876	135
8.5	2.0	2.4	10. 71353	14.430876	135
8.5	2.0	2.5	10. 63115	14.430876	135
8.5	2.0	2.6	10. 54876	14.430876	135
8.5	2.0	2.7	10. 46637	14.430876	135
8.5	2.0	2.8	10. 38401	14.430876	135
8.5	2.0	2.9	10. 30171	14.430876	135
8.5	2.0	3.0	10.21949	14.430876	135

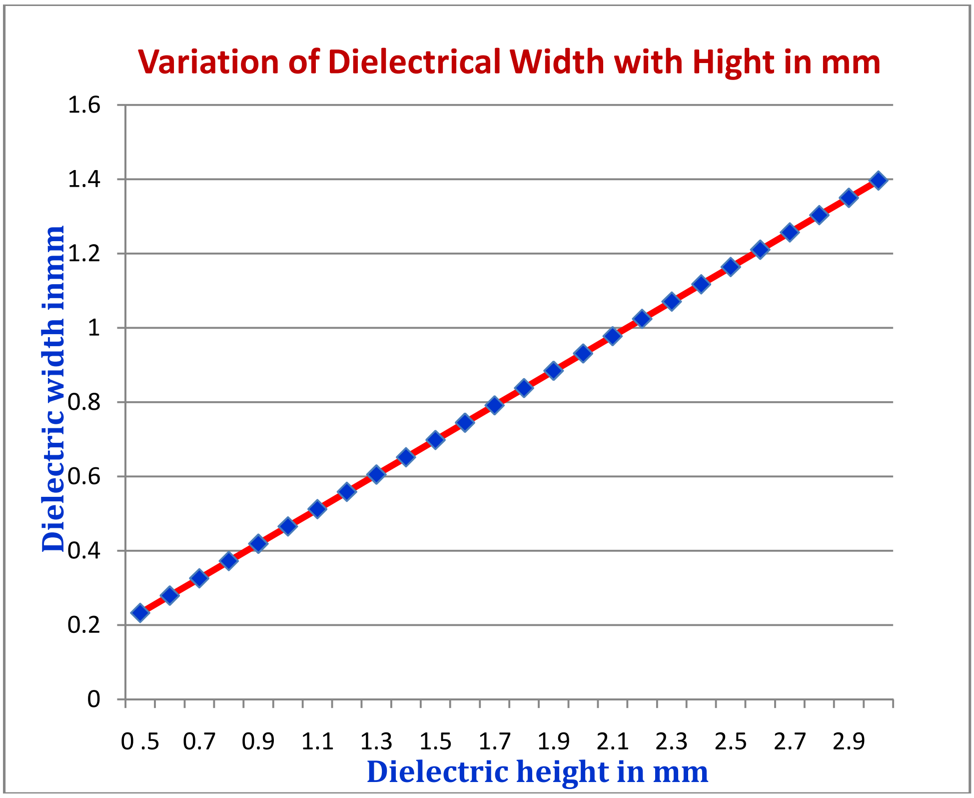




Determination of parameters of patch antenna

f_r=8.5 GHz Z_0=135Ω and Electrical Length = 0.001

Substrate parameter		
Dielectric height(h)mm	Dielectric Width(w)mm	Length(L)mm
0 .5	0.23277	7.75886
0.6	0.27933	7.75886
0.7	0.32588	7.75886
0.8	0.37244	7.75886
0.9	0.41899	7.75886
1.0	0.46555	7.75886
1.1	0.51210	7.75886
1.2	0.55866	7.75886
1.3	0.60521	7.75886
1.4	0.65177	7.75886
1.5	0.69832	7.75886
1.6	0.74488	7.75886
1.7	0.79144	7.75886
1.8	0.83799	7.75886
1.9	0.88455	7.75886
2.0	0.93110	7.75886
2.1	0.97766	7.75886
2.2	1.02421	7.75886
2.3	1.07077	7.75886
2.4	1.11732	7.75886
2.5	1.16388	7.75886
2.6	1.21043	7.75886
2.7	1.25699	7.75886
2.8	1.30354	7.75886
2.9	1.35010	7.75886
3.0	1.39665	7.75886



Measurements of return loss

Micro strip antennas in respect of their potential advantages with the property of light weight, low profile and flushing mounting suffer a serious defect of narrow impedance band width. This is due to the gap in the substrate with the radiator. The improvement in the impedance and band width of micro strip antenna can be achieved using shunt impedance between the given patch and the ground plane. A band width of 10 % less is obtained for the driven patch.

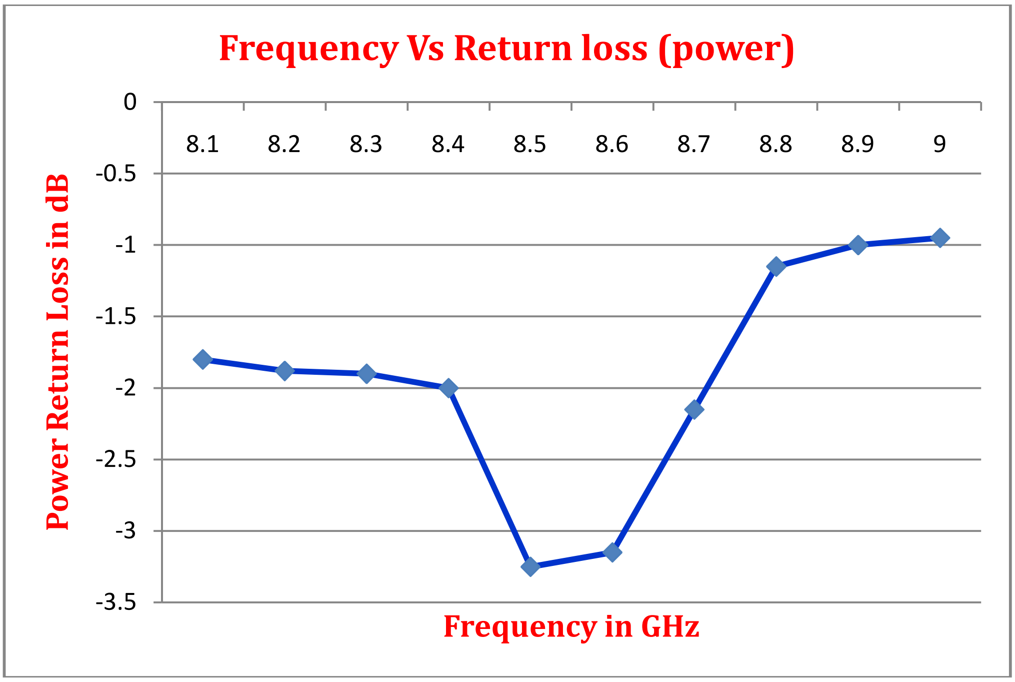
To study the radiation characteristics, the feed point for the radiator element should be properly fixed which is operating under TEM mode. Usually the feed point is at the centre of the element. The maximum radiation efficiency is observed when the input impedance of the feeder and the input impedance of the element are same. But in practice it is difficult to achieve and we have tried to have best possible matching between the two by fixing the feeder point at a distance of $\frac{\lambda_g}{4}$.

The input impedance of micro strip element was measured by calculation which is 135 Ω. This value is adjusted with the location of feeder cable to have maximum radiation.

The software used to model and simulate the micro strip patch antenna is IE3D software. The electromagnetic simulator analysis 3D multilayer structures of general shapes. It has been widely used in the design of patch antenna, wire antenna and other RF/wireless antennas. It can be used for determining VSWR (voltage standing wave ratio) and current distributions as well as the radiation patterns.

Measurements of return loss

Frequency (GHz)	Return loss (power) (dB)
8.1GHz	-1.8dB
8.2 GHz	-1.88 dB
8.3 GHz	-1.9 dB
8.4 GHz	-2.0 dB
8.5 GHz	-3.25 dB
8.6 GHz	-3.15 dB
8.7 GHz	-2.15 dB
8.8 GHz	-1.15 dB
8.9 GHz	-1.0 dB
9 GHz	-0.95 dB



For the measurement of return loss for a band of frequency near the designed value are measured. The radiation patterns are computed for the E-plane and h-plane by approximating the expressions for the values obtained.

Conclusion

Depending up on the applications of the micro strip antenna in respect of plane polarization, strip in the shape of square, rectangular and circular is preferred. The design consideration is mainly dependent on the application of antenna is cell phones at RF frequency and missiles or satellites at microwave frequency. The patch antenna has the advantage of thin and light weight. The radiation characteristics of the antenna are mainly dependent on substrate material. Hence dielectric constant of substrate places a vital role in respect of the band width and matching conditions of the antenna in a communication system. The substrate material has no changes in electrical properties either at RF frequency or at micro wave frequency. Based on the selection of substrate, the arrays can be designed for improving the band width. A feed point for the patch element can be varied from the edge of the antenna element, so that equal power distributed with a phase difference for required polarization. From the graph of return loss versus frequency, the centre frequency for the operation of patch antenna can be obtained and from the graph even return loss corresponding to -0.95 dB can be marked to obtain the band width of the antenna. The obtained range of frequency is much closer to a desired frequency 8.4GHz. The effectiveness of the matching conditions is studies in the respect of varying thickness of substrate from the ground plane. So far various values of h, the thickness of the substrate, the input impedance is found to be 135Ω. This clearly shows that the matching of the feeding cable is independent of the thickness of the substrate which is required. The return loss of the patch antenna is mainly dependent on the location of the feeder cable for uniform distribution of radiation. Due to limitations of studies the return loss is measured only at desired frequency. The micro strip patch antenna radiates normal to the patch surface where the elevation of the pattern has a significant role from $\phi = 0^0$ to 90^0.

The evaluation of E_y is the electric vector along Y-axis is computed and similarly the magnetic field component along Z- axis is calculated. So that the resultant propagation is perpendicular to the plane containing these two vectors.

The radiation pattern either in polar form or in Cartesian form can be obtained by choosing the quantities i.e. the length of the patch and the effective length $L_{eff.}$

$$E_y = E_0 \cos\left(\frac{\pi}{L} L_{eff}\right)$$

In our study L and L_{eff} are varied in order to know the strength of the electric vector for different values. Similarly the magnetic field vector h_z is also computed using the relations

$$H_z = H_0 \cos\left(\frac{\pi}{L} L_{eff}\right)$$

The results calculated are presented in the table.

From the results it is concluded that the radiation of the patch antenna is effective in perpendicular direction of the plane containing E_Y and H_z vectors.

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