International Journal of Electronics and Communication Engineering (IJECE)
ISSN(P): 2278-9901; ISSN(E): 2278-991X
Vol. 4, Issue 5, Aug - Sep 2015, 45-56

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

DESIGN OF AND ANALYSIS OF RECTANGULAR PATCH ANTENNA AND ARRAYS

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ABSTARCT

Antenna is an electronic device which converts electrical power in to electromagnetic energy. Antenna radiates electromagnetic signals in all directions by adopting different types of feeding techniques. Microstrip antennas are widely used in wireless communication systems for microwave frequency range because they can be easily fabricated and weighs less [1]. Micro strip patch antennas include reduced weight, easy fabrication, conformability to mounting hosts and bandwidth enhancement. Conventional micro strip patch antenna suffers from very narrow bandwidth, which is typically about 5% bandwidth with respect to the center frequency, low power, and excitation of surface waves and relatively high level of cross polarization radiation which limits their applications. Researchers have developed a number of numerical methods to ease the design procedures of micro strip antennas to meet broadband criteria [10].

In the present work design and analysis of micro strip patch antenna at 5 GHz has done whose width is 23mm and length 19mm and thickness of 0.0415mm.In this antenna design different width of the arm of patch antenna is analyzed to study on the performance of frequency resonance. From the analysis, the wider the width will lower the resonance frequency of the antenna. Large Micro strip array antennas in both linear and planar array systems are designed in the present work. which are used in WLAN applications, Navigation systems. The results are compared with the isotropic antenna array system which is obtained with good agreement.

KEYWORDS: Microstrip Patch Antenna, Array Antennas, Patern Multiplication, WLAN and Navigation Systems

INTRODUCTION

In telecommunication, there are several types of microstrip antennas (also known as printed antennas) the most common of which is the microstrip patch antenna or antenna. A microstrip or patch antenna is a low profile antenna that has a number of advantages over other antennas .It is lightweight, inexpensive, and easy to integrate with accompanying electronics. An advantage inherent to patch antennas is the ability to have polarization diversity [10]. A microstrip patch antenna (MPA) consists of a conducting patch of any planar or non-planar geometry on one side of a dielectric substrate with a ground plane on other side. It is a popular printed resonant antenna for narrow-band microwave wireless links that require semi-hemispherical coverage. Patch antennas can easily be designed to have vertical, horizontal, right hand circular (RHCP) or left hand circular (LHCP) polarizations, using multiple feed points, or a single feed point with asymmetric patch structures.

This unique property allows patch antennas to be used in many types of communications links that may have varied requirements. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible[10]. Because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices. Microstrip antennas are becoming increasingly useful because they can be printed directly onto circuit board. They are becoming widespread within the mobile phone market. Patch antennas are low cost, have a low profile and easily fabricated. These patch antennas are used for the simplest and demanding applications. Rectangular geometries are separable in nature and their analysis is simple [9]. A microstrip patch antenna (MPA) consists of a conducting patch of any non-planar or planar geometry on one side of a dielectric substrate and a ground plane on other side[5]. It is a printed resonant antenna for narrow-band microwave wireless links requiring semi-hemispherical coverage. The rectangular and circular patches are the basic and most commonly used microstrip antennas [10].

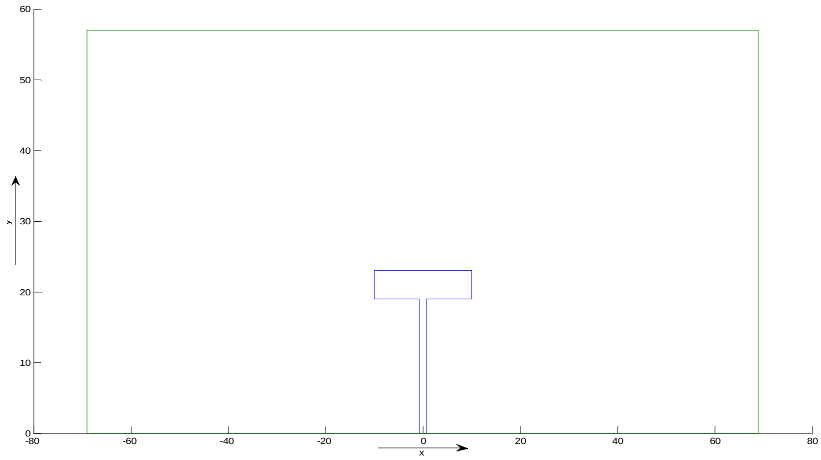

Figure 1

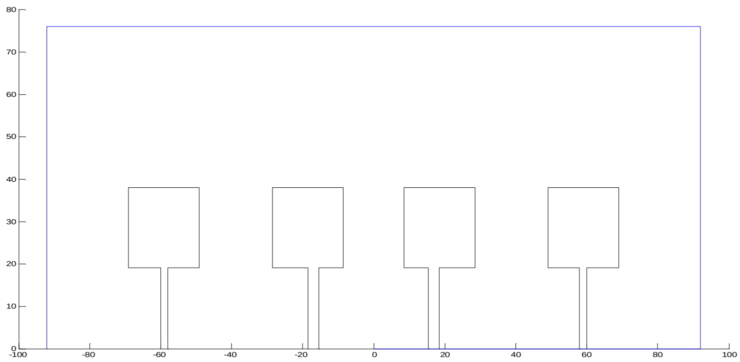

Figure 2: Array of Rectangular Patch Antenna

There are different feeding techniques available to feed microstrip patch antennas. They are: microstrip line feed, coaxial feed, aperture coupled feed and proximity coupled feed. Proximity coupled feeding technique is also called as the electromagnetic coupling scheme. Two dielectric substrates are used and the feed line is between the two substrates. The radiating patch is on top of the upper substrate[4]. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%).The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers which need proper alignment. In our design we use microstrip line feed. The microstrip patch antenna with microstrip feed is as follows.

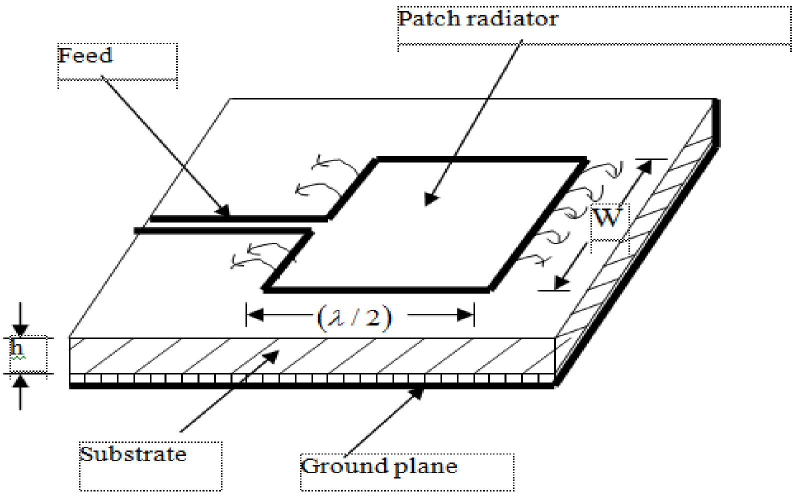

Figure 3: Rectangular Micro Strip Patch Antenna

In the above figure, a conducting strip is connected directly to the edge of the microstrip patch**.** Hence it is a microstrip feed. The commonly used substrates are FR-4 substrate and RT DUROID 5880 substrates[10].

DESIGN OF RECTANGULAR MICROSTRIP PATCH ANTENNA

The frequency of operation of the patch antenna of Figure is determined by the length L[10]. The center frequency will be approximately given by: $f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_o \varepsilon_r \mu_o}}$.

The width of the patch element (W) is given $W = \frac{c}{2 f_o \sqrt{\frac{(\varepsilon_r + 1)}{2}}}$

The effective length (L_{eff}) is given by $L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}}$,

The length extension (ΔL)

$$\Delta L = 0.412 \frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)}$$

The actual length (L) of patch is obtained by $L = L_{eff} - 2\Delta L$

Theoretical Values and Calculations

To calculate the dimensions of microstrip patch antenna, the following theoretical values and formulas are required.

The width of the patch element (W) is given $W = \frac{c}{2 f_o \sqrt{\frac{(\varepsilon_r + 1)}{2}}}$

Where W is the width of patch element, c is the velocity of light= 3x10^8 m/s, f_o is the optimum frequency = 5 GHz. Substituting c = 3x10^8 m/s, ε_r = 2.2, and f_o = 5 GHz, then W =2.3717cm.The effective of the dielectric constant (ε_{reff}) depending on the same geometry (W, h) but is surrounded by a homogeneous dielectric of effective permittivity ε_{reff}, whose value is determined by evaluating the capacitance of the fringing field.

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

Substituting ε_r = 2.2, W =2.3717cm, and h =0.1575cm, then ε_{reff} εreff = 2.1074cm.

The effective length (L_{eff}) is given by $L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}}$, Substituting, c=3x10^{8}m/s. ε_{reff} = 2.0475cm, and f_o =5GHz, then L_{eff} =2.0665cm.The length extension(ΔL): $\Delta L = 0.412 \frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)}$

Substituting ε_{reff} =2.1074 c m , W= 2.3717c , and h =0.0787cm, then ΔL= 0.041469cm.

The actual length (L) of patch is obtained by $L = L_{eff} - 2\Delta L$

Substituting ΔL= 0.041469cm, and L_{eff} = 2.0665cm, then L=1.9835cm.

by varying the frquency from 1GHz to 12GHz, we calculate the size of the patch antenna.It is observed that if the frequency (GHz) is increased, the patch antenna size is decreased and is presented in table 1

Table 1: Variation of Width and Length for Different Frequencies

Frequency(GHz)	Width(cm)	Length(cm)
1	11.8	29.52
2	4.68	4.63
3	3.96	3.29
4	2.96	2.4
5	2.3	1.9
6	1.977	1.59
7	1.7	1.39
8	1.4	1.29
9	1.32	1.002
10	1.1904	0.877
11	1.082	0.776
12	0.992	0.577

Radiation Pattern of Patch Antenna

H-plane radiation pattern is[10]: $$F(\theta) = \frac{\sin\left(\frac{k_o W}{2}\cos\theta\right)}{\frac{k_o W}{2}\cos\theta}\sin\theta \quad (1)$$

E-plane radiation pattern is: $$F_T(\phi) = \frac{\sin\left(\frac{k_o h \cos\phi}{2}\right)}{\frac{k_o h \cos\phi}{2}} \cos\left(\frac{k_o L}{2}\cos\phi\right) \qquad (2)$$

The array factor of linear array is given by[8]

$$AF = \frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)} \qquad (3)$$

The array factor of planar array is given by $$S_{xM} = \frac{1}{M}\frac{\sin\left(M\frac{\psi_x}{2}\right)}{\sin\left(\frac{\psi_x}{2}\right)};\ S_{yN} = \frac{1}{N}\frac{\sin\left(N\frac{\psi_y}{2}\right)}{\sin\left(\frac{\psi_y}{2}\right)}$$

$AF=S_{xM}*S_{yN}$ (4)

The resultant pattern of an array of non-isotropic identical radiators is given by[8]

$$E = f(\theta,\phi)F(\theta,\phi)\times((f_p(\theta,\phi)+F_p(\theta,\phi))$$

Where $f(\theta,\phi)$ = Element field pattern; $f_p(\theta,\phi)$ = Element phase pattern

RESULTS

The results are obtained by using the equations 1 to 4 at the resonant frequency 5GHz.The patch antenna width and length are calculated and obtained the values are 23mm, 19mm respectively. The radiation patterns are obtained in H-plane & E-plane using equations 1,2. The results are presented from figures 5 to 8 in both polar and rectangular form. The patch arrays in both linear and planar array system are also designed by using the pattern multiplication principle. The results are presented from figures 9 to 29. The radiation patterns are drawn for N=5, 10,20,40,80,100. These are compared with the isotropic radiators and are obtained with good agreement in both linear and planar array system. These are useful in WLAN applications and Navigation systems

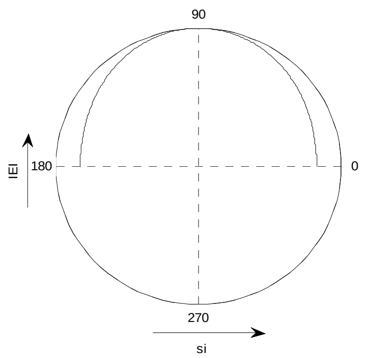

Figure 4: Polar form of Patch Antenna H-Plane

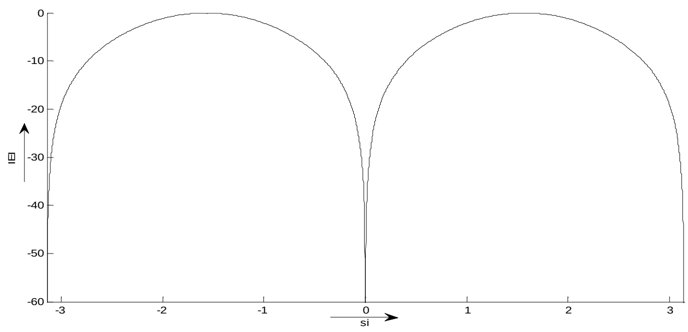

Figure 5: Rectangular Plot of Patch Antenna H-Plane

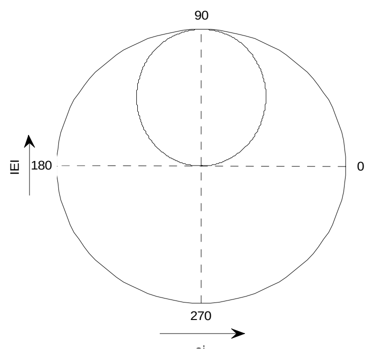

Figure 6: Polar form of Patch Antenna E-Plane

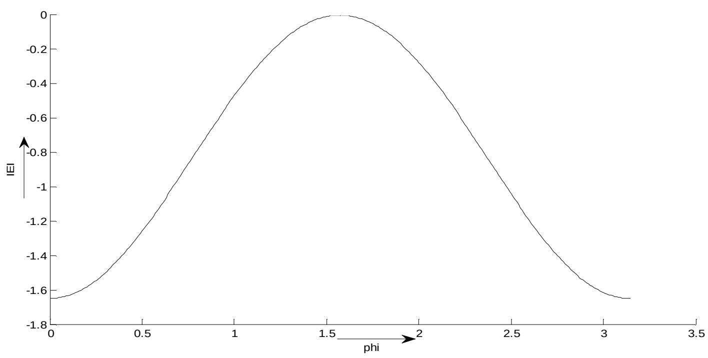

Figure 7: Rectangular Plot of Patch Antenna E-Plane

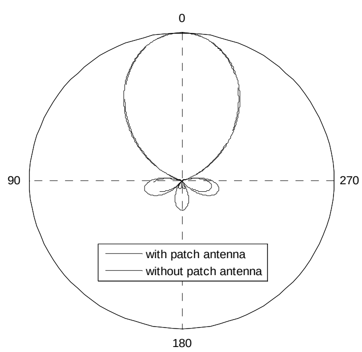

Figure 8: Radiation Pattern of Linear Patch Array Antenna for N=5 in Polar Form

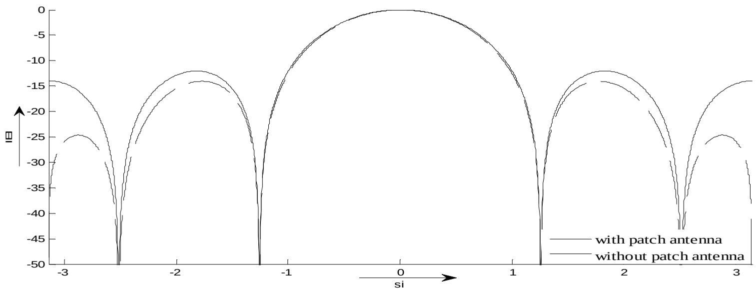

Figure 9: Radiation Pattern of Linear Patch Array Antenna for N=5 in Rectangular Form

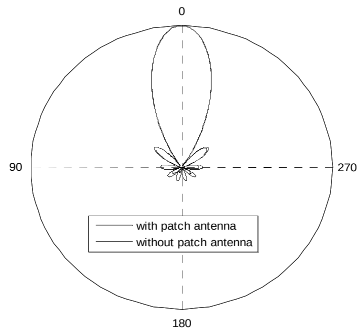

Figure 10: Radiation Pattern of Linear Patch Array Antenna for N=10 in Polar Form

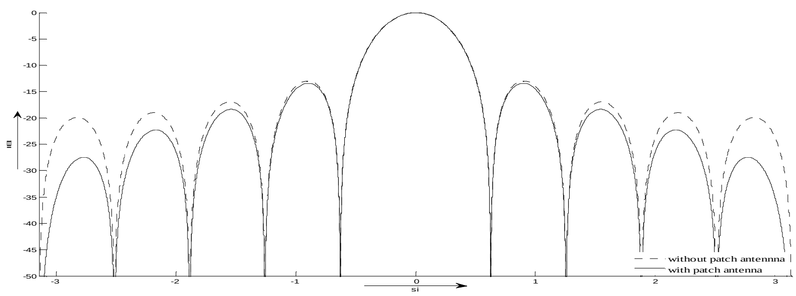

Figure 11: Radiation Pattern of Linear Patch Array Antenna for N=10 in Rectangular Form

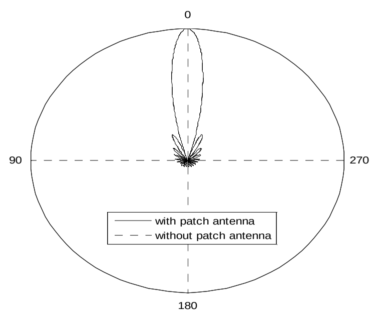

Figure 12: Radiation Pattern of Linear Patch Array Antenna for N=20 in Polar Form

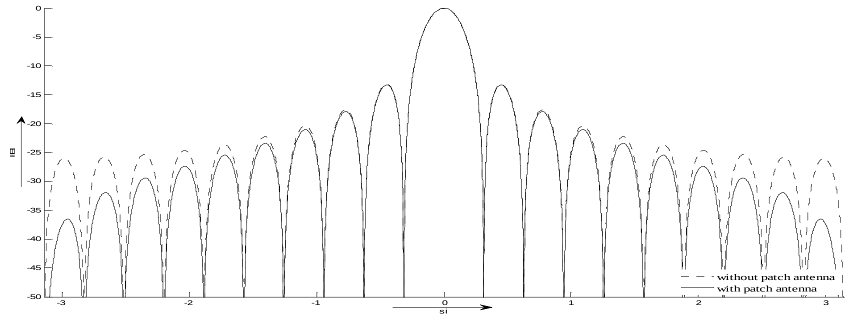

Figure 13: Radiation Pattern of Linear Patch Array Antenna for N=20 in Rectangular form

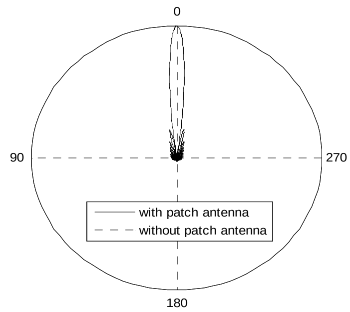

Figure 14: Radiation Pattern of Patch Antenna for N=40 Elements of Linear Array in Polar form

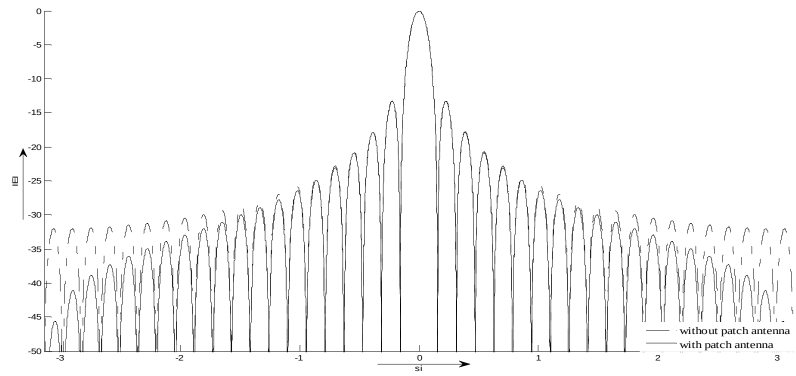

Figure 15: Radiation Pattern Patch Antenna for N=40 Elements of Linear Array in Rectangular form

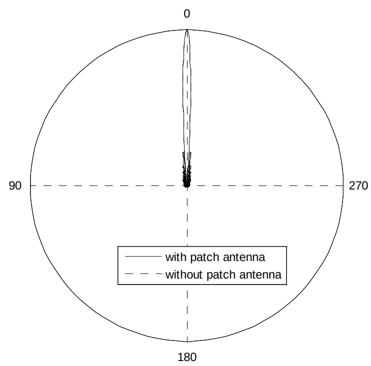

Figure 16: Radiation Pattern of Patch Antenna for N=80 Elements of Linear Array in Polar form

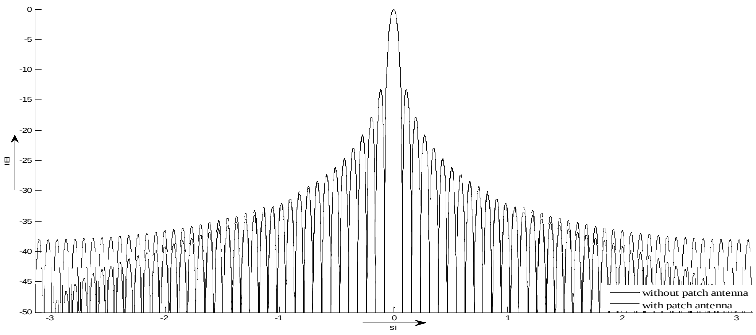

Figure 17: Radiation Pattern Patch Antenna for N=80 Elements of Linear Array in Rectangular form

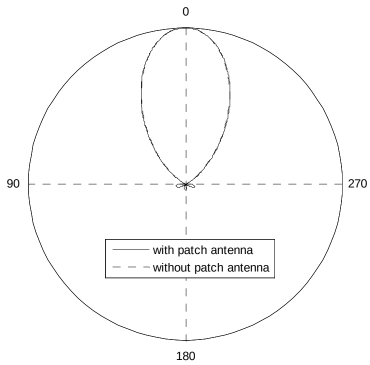

Figure 18: Radiation Pattern of Patch Antenna for N=M=5 Elements of Planar Array in Polar form

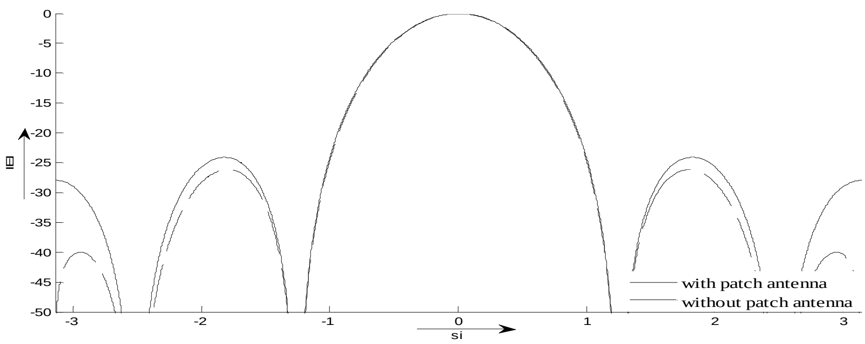

Figure 19: Radiation Pattern of Patch Antenna for N=M=5 Elements of Planar Array in Rectangular form

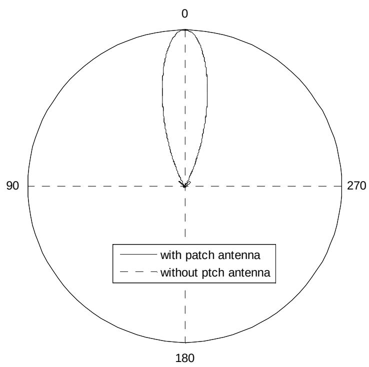

Figure 20: Radiation Pattern of Patch Antenna for N=M=10 Elements of Planar Array in Polar form

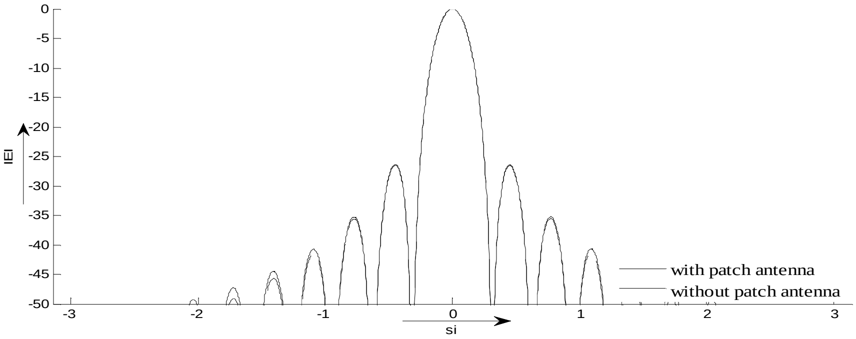

Figure 21: Radiation Pattern of Patch Antenna for N=M=10 Elements of Planar Array in Rectangular form

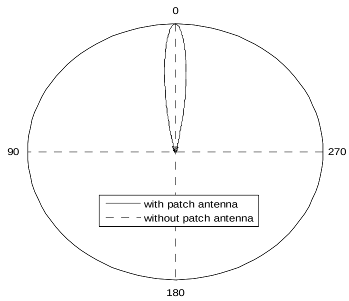

Figure 22: Radiation Pattern of Patch Antenna for N=M=20 Elements of Planar Array in Polar form

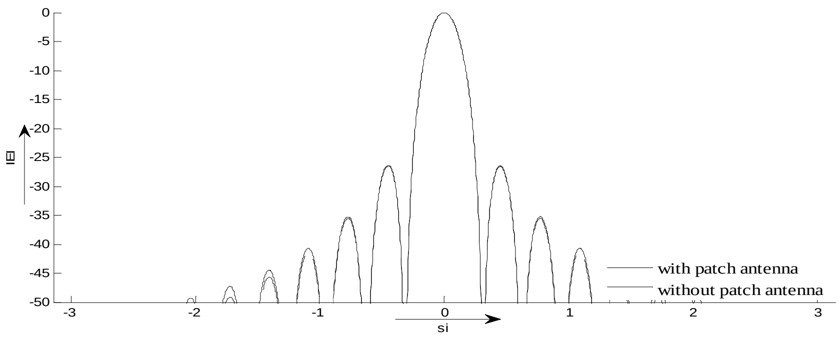

Figure 23: Radiation Pattern of Patch Antenna for N=M=20 Elements of Planar Array in Rectangular form

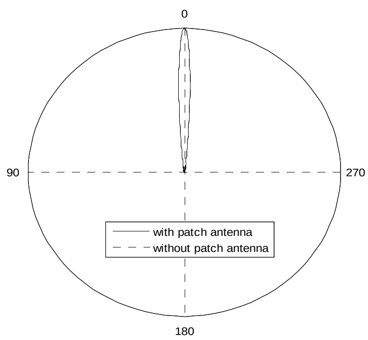

Figure 24: Radiation Pattern of Patch Antenna for N=M=40 Elements of Planar Array in Polar form

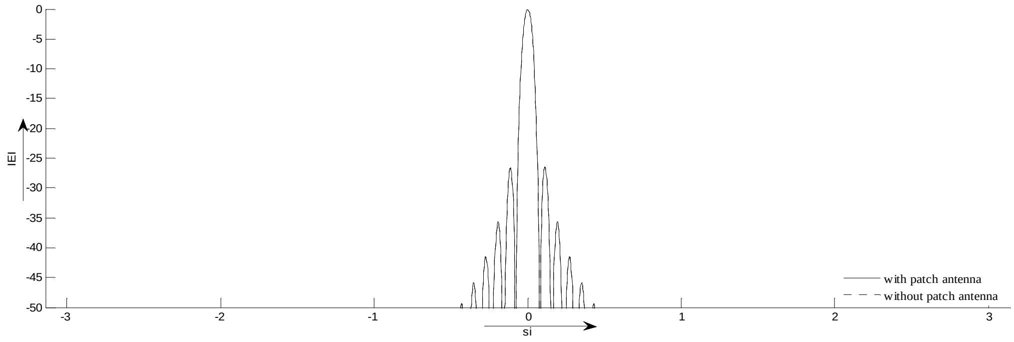

Figure 25: Radiation Pattern of Patch Antenna for N=M=40 Elements of Planar Array in Rectangular form

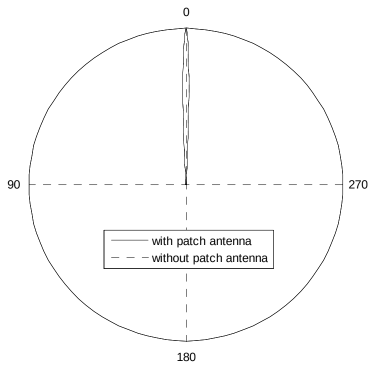

Figure 26: Radiation Pattern of Patch Antenna for N=M=80 Elements of Planar Array in Polar form

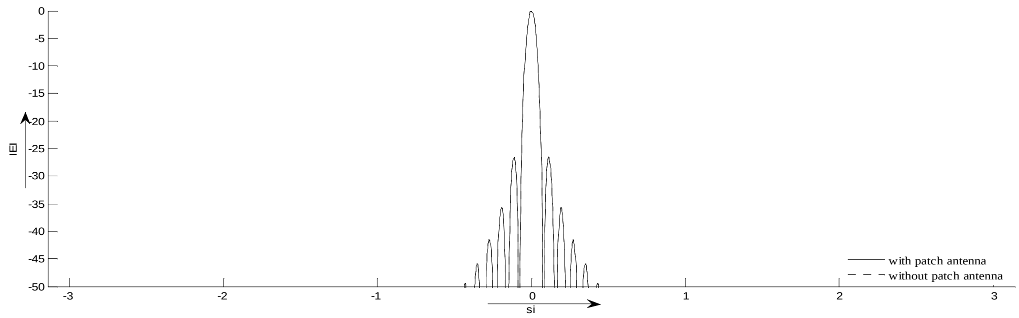

Figure 27: Radiation Pattern of Patch Antenna for N=M=80 Elements of Planar Array in Rectangular form

CONCLUSIONS

The proposed patch antenna is designed and the specifications are

Length (L)=1.9cm,width(W)=2.3cm,height(h)=0.0787cm,ΔL=0.041469cm at 5GHz frequency. A low cost microstrip patch antenna for WLAN operation in the 5 GHz band has been proposed here. The proposed patch antenna has a narrow width and easy to implement. The frequency resonance of the antenna has been shifted and band width of patch is between 11 to 13% can be achieved. The patch antenna field patterns are plotted for different number of elements the array field patterns of both linear array and planar array are plotted and their results are presented.Using pattern multiplication principle the patch array radiation patterns are also drawn for different values of N and M. It is observed that the first side lobe level is -13.5 dB, the main beam width reduced when the numbers of elements are increased. These are useful in point to point communications and radar.

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