INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Design of Inset-Fed Ceramic Patch Array Antenna for Pseudolite Based Positioning Applications

K. Rosili Sipora
P.G. Student, Department of E.C.E, Sir C. R. Reddy College of Engineering, Eluru, India.
K. J. Silva Lorraine
Assistant Professor, Department of E.C.E, Sir C.R. Reddy College of Engineering, Eluru, India
D. Venkata Ratnam
Associate Professor, Department of E.C.E, K L University, Guntur, India

Abstract: *Pseudolite based positioning is designed to be used as an alternative to GPS when receiver faces low position accuracy in areas where the satellite signals are less available or non-existent.. However, one of the major problems faced by the pseudolite based navigation system is "Multipath" effect. It is mainly caused by reflections of the signal from the ground or near-by building or other obstacles which limits the effective range of truthful positioning. In this paper, design of Inset-fed ceramic patch array antenna using HFSS has been proposed to overcome the problem. Simulation results present the influence of increase in element number and influence of inter-element spacing on the design. Also, radiation patterns for rectangular and elliptical patch array antenna using different feeds are simulated, presented and comparatively analyzed in this paper.*

Keywords: *Pseudolite, Multipath, Patch Array, HFSS, Gain, Directivity*

1. Introduction

The Global Positioning System (GPS) is a world–wide satellite based navigation system. However, GPS positioning in some areas such as urban canyons and deep open cut mines are not reliable due to non-visibility of sufficient number of satellites [1]. In such situations, the receiver is unable to track minimum number of satellite signals. Pseudolite (PLs) or Pseudo-satellites which are ground based transmitters can be employed which transmits GPS like signal to augument and provide accuracy, availability, integrity and continuity in such an environment [2]. However due to presence of obstacles or nearby building it causes multipath effect. This paper discusses about Multipath effect, and HFSS design of Inset-fed Ceramic Patch array receiver antenna design operating at 1.57GHz.

2. Multipath Effect

Multipath propagation is a real challenge for microwave tracking systems. The multipath effects that occur under severe propagation conditions can become crucial for performance of such a system. Multipath is the effect of transmitted signals that arrive at the receiver's antenna on different paths in addition to the direct signal, when they encounter a reflective or a separation surface between two environments [3]. Multipath signals are delayed with respect to the direct signal in amplitude, phase and polarisation and it is characterized by the reflective surface and the number of reflections.

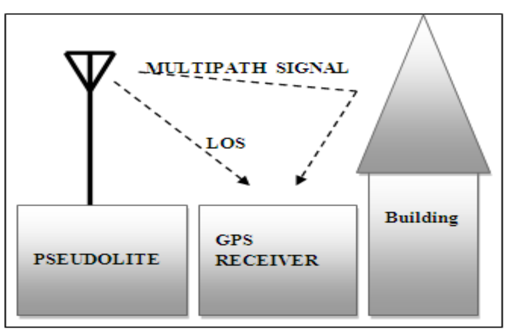

Figure1: Illustration of Multipath effect

Pseudolite multipath has some different characteristics compared to GPS signals. The multipath from pseudolites is not only from reflected signals from the surface, but also from the pseudolite transmitter itself. Secondly, when compared with GPS, multipath from pseudolites is very serious because the elevation angle from the receiver to the pseudolite transmitter is quite small. Thirdly, if the pseudolite and receiver are both stationary, the multipath bias will be a constant. Hence, the influence of multipath from pseudolite cannot be mitigated and reduced to the same extent overtime as in the case of GPS. Finally, the multipath will significantly increase the noise level of the measurement in a dynamic environment, because it is very hard to eliminate.

3. Single Element Study

3.1 Theory

Patch antenna design at 1.57 GHz is the overall objective of this section. To achieve this overall objective, the primary task is to choose a suitable geometry of the patch for the antenna. The proposed shape is rectangular and elliptical.

In its basic form, microstrip antennas are similar to parallel plate capacitors. Both have parallel plates of metal layer and a sandwiched dielectric substrate between them. But in microstrip antenna, one of these metal plates is infinitely extended than the other, to form the ground plane; whereas the smaller metal plate is described as radiating patch.

The radiation of the microstrip antenna is determined from the field between the metal patch and the ground plane. Opposite charges are established on the bottom of patch and top of the ground plane when the patch is excited. The attractive force will hold most of the charges between the two surfaces. In the meantime, the repulsive forces of the same charges on the patch surface will push some of the charges to the edges creating fringing fields which is the reason why patch antenna resonates [4].

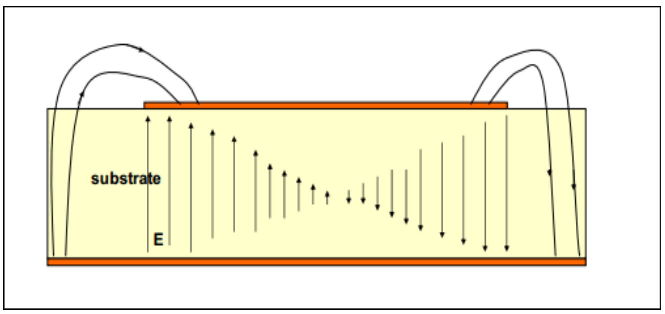

Fig. 2 Radiation mechanism of patch antenna

3.2. Design of Single Element Patch Antenna

3.2.1. Selection of substrate

One of the major steps in designing a patch antenna is to choose suitable substrate of appropriate thickness, permittivity and loss tangent. The substrate is often a dielec- tric with a permittivity of between 2.1 and 25. An RT-Duroid substrate of dielectric constant 2.2 and dielectric loss tangent of 0.009 is used.

3.2.1. Type of feeding and shape of antenna

The four most common techniques are Microstrip feed, Coaxial (Probe) feed, Aperture coupling and Proximity coupling. Inset-fed and Probe-fed are used as there are easy to implement but this type of feeding generates a parasite radiation which affects the radiation pattern. Rectangular and elliptical shapes are considered and comparative results are mentioned below.

3.2.3. Design equations

For rectangular patch antenna, suppose patch length is L, patch width is W, dielectric thickness is h, dielectric constant is ε_r, light speed is c, resonant frequency is fr, wavelength is λ then[5]

$$f_{r}=\frac{C}{2L\sqrt{(\varepsilon_{reff})}} \quad (1)$$

$$W=\frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (2)$$

$$L = \frac{c}{2\sqrt{\varepsilon r\, fr}} \quad (3)$$

For Elliptical patch, the expression for the radius

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi F \varepsilon r}\left[ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \quad (4)$$

Where

$$F = \frac{8.791 * 10^9}{fr\sqrt{\varepsilon r}} \quad (5)$$

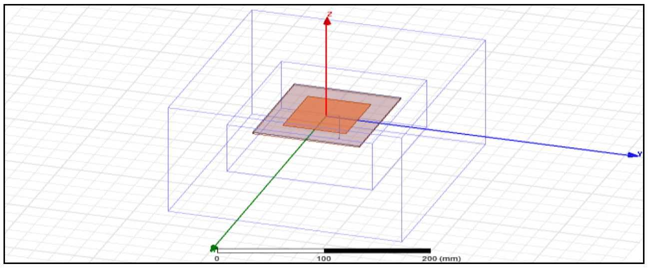

Figure 3: HFSS model for Probe-fed rectangular patch antenna

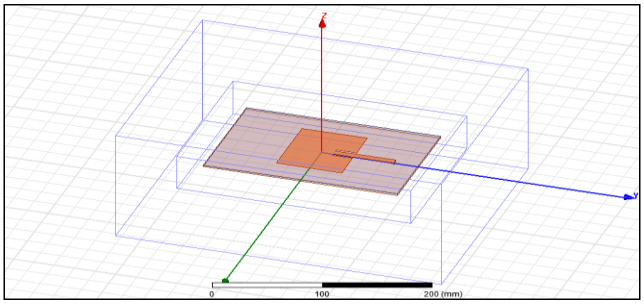

Figure 4: HFSS model for Inset-fed rectangular patch antenna

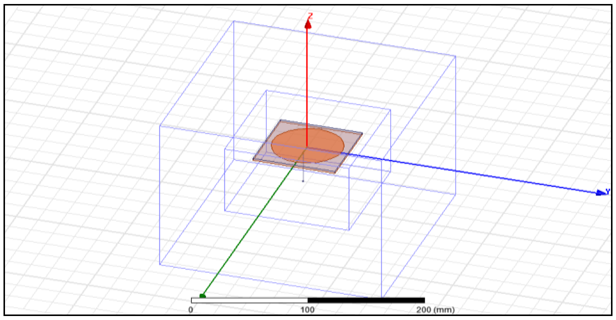

Figure 5: HFSS model for Probe-fed elliptical patch antenna

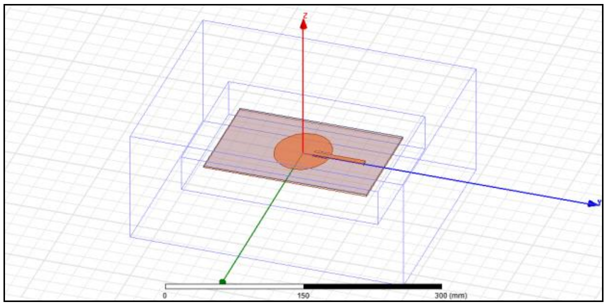

Figure 6: HFSS model for Inset-fed elliptical patch antenna

Figure 3 and Figure 4 shows rectangular patch antenna using probe and inset fed respectively. Figure 5 and Figure 6 shows elliptical patch antenna using probe and inset fed respectively.

4. Microstrip Patch Antenna Array

Antenna arrays are basically a collection of radiating elements, geometrically arranged in a specific manner, to generate the required radiation pattern. The antenna array can be used to Increase the overall gain, Cancel out interference from a particular set of directions, Steer the array so that it is most sensitive in a particular direction, determine the direction of arrival of the incoming signals.

The radiation pattern of the network depends on many parameters. Referring to studies performed on more antenna arrays that the expression of the general network is as follows [6]

$$E_{total}(\theta,\emptyset) = AF(\theta,\emptyset) \times f(\theta,\emptyset) \quad (6)$$

The term f (θ, φ) represents the vector electrical potential created in the region of radiation by the reference antenna. It only depends on the type of antenna and power distribution. It is called element factor. The term AF (θ, φ) depends only on the relative positions of antennas in the series and relationships between the current distributions. This is the array factor. The angles θ, φ represent the coordinates of a polar M in space having a distance r from the array.

4.1. Types of Microstrip patch arrays

Linear array: A uniform array is defined by uniformly-spaced identical elements of equal magnitude with a linearly progressive phase from element to element. It is assumed that each succeeding element has a progressive phase lead current excitation relative to the preceding one. An array of identical elements with identical magnitudes and with a progressive phase is called a uniform array.

The AF can be obtained by considering the individual elements as point (isotropic) sources. If the elements are of any other pattern, the total field pattern can be obtained by simply multiplying the AF by the normalized field pattern of the individual element.

$$AF = \frac{\sin\left({}^{N\Psi}/_{2}\right)}{N\sin\left({}^{\Psi}/_{2}\right)} \quad (7)$$

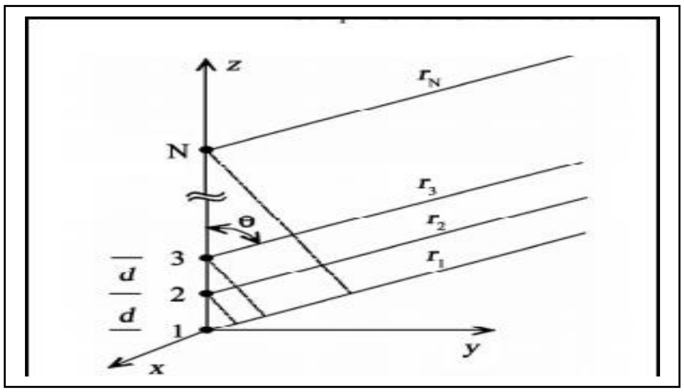

Figure 7: Linear array

The function ψ is defined as the array phase function and is a function of the element spacing, phase shift, frequency and elevation angle

$$\psi = \beta d \cos\theta + \alpha \quad (8)$$

Planar array: Planar arrays provide directional beams, symmetrical patterns with low side lobes, much higher directivity (narrow main beam) than that of their individual element. In principle, they can point the main beam toward any direction.

If N such arrays are placed at even intervals along the y direction, a rectangular array is formed. We assume again that they are equispaced at a distance dy and there is a progressive phase shift β_y along each row. We also assume that the normalized current distribution along each of the x-directed arrays is the same but the absolute values correspond to a factor of n (n = 1, 2, 4,…., N). Then, the AF of the entire M×N array is

$$AF(\theta,\phi) = \left[\frac{1}{M}\frac{\sin\left(M\frac{\psi_x}{2}\right)}{\sin\frac{\psi_x}{2}}\right]\left[\frac{1}{N}\frac{\sin N\frac{\psi_y}{2}}{\sin\frac{\psi_y}{1}}\right] \quad (9)$$

The functions ψ_x and ψ_y are de- fined as the array phase function and are a function of the element spacing, phase shift, frequency and elevation angle.

$$\psi_x = d_x \sin\theta \cos\phi + \beta_x \quad (10)$$

$$\psi_y = d_y \sin\theta \cos\phi + \beta_y \quad (11)$$

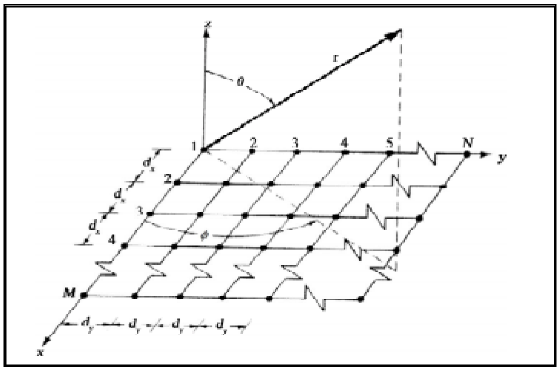

Figure 8: Planar array

4.3 HFSS models of Inset-fed rectangular arrays

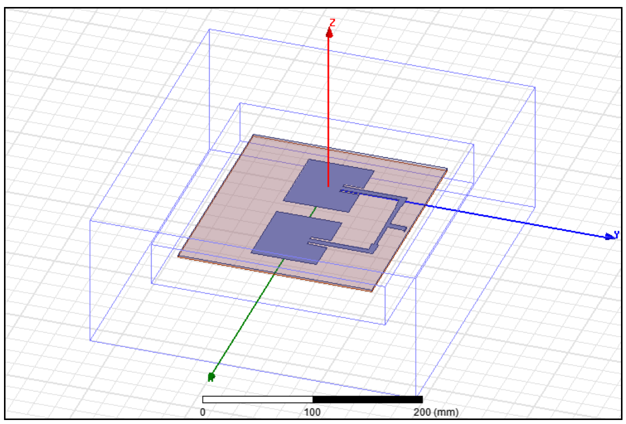

*Figure 9: HFSS model of Inset fed linear rectangular patch array (1*2)*

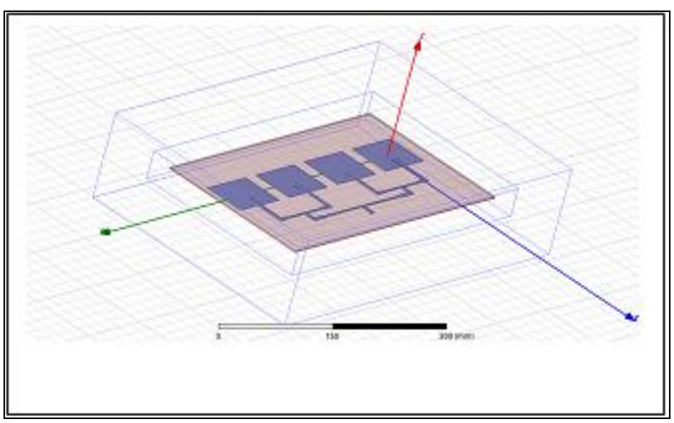

*Fig .10 HFSS model of Inset fed linear rectangular patch array (1*4)*

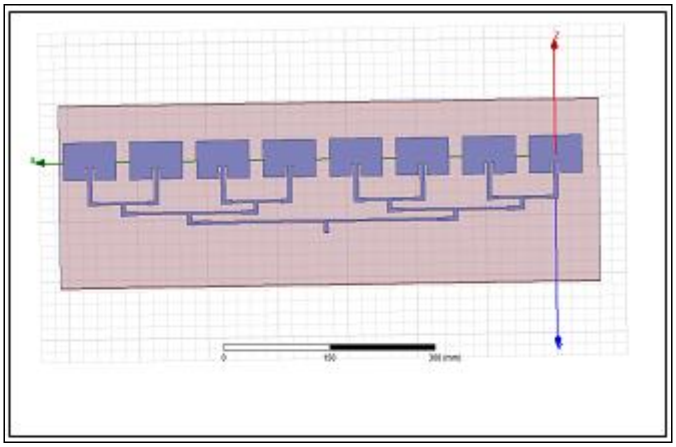

*Figure 11: HFSS model of Inset fed linear rectangular patch array (1*8)*

5. Results and Discussions

The Fig 12- Fig 14 shows Return loss, VSWR and Gain radiation pattern of inset-fed rectangular patch antenna.

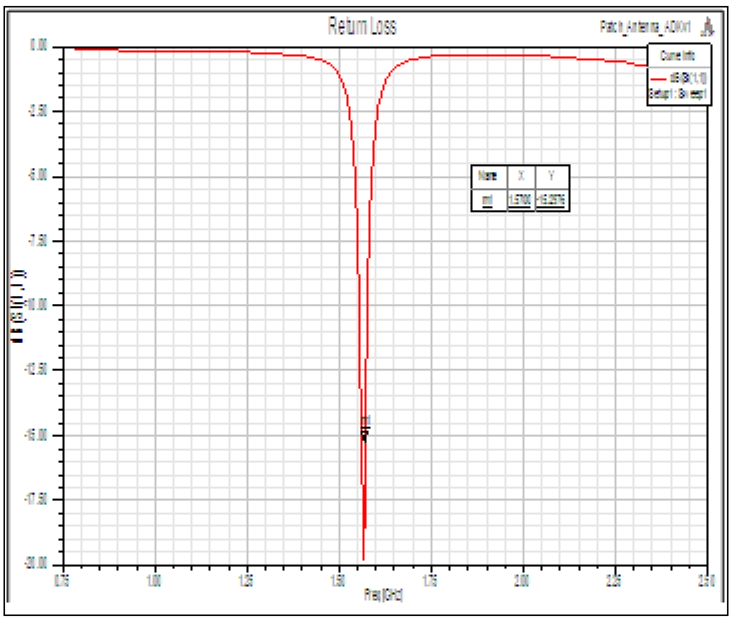

Figure 12: Return loss plot of inset fed rectangular patch antenna

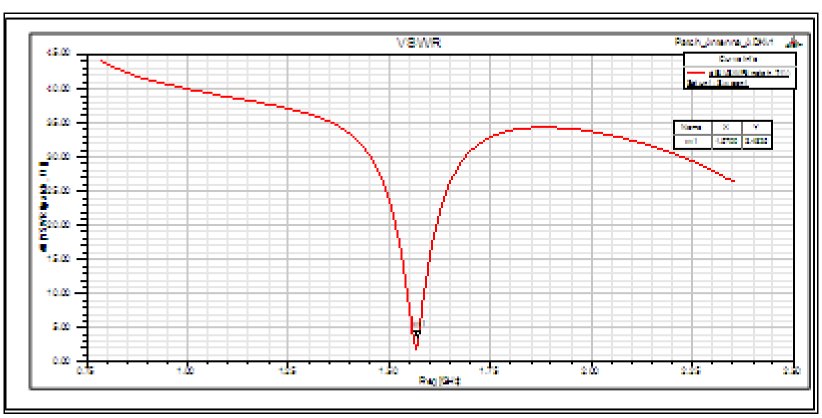

Figure13: VSWR plot for inset-fed rectangular patch

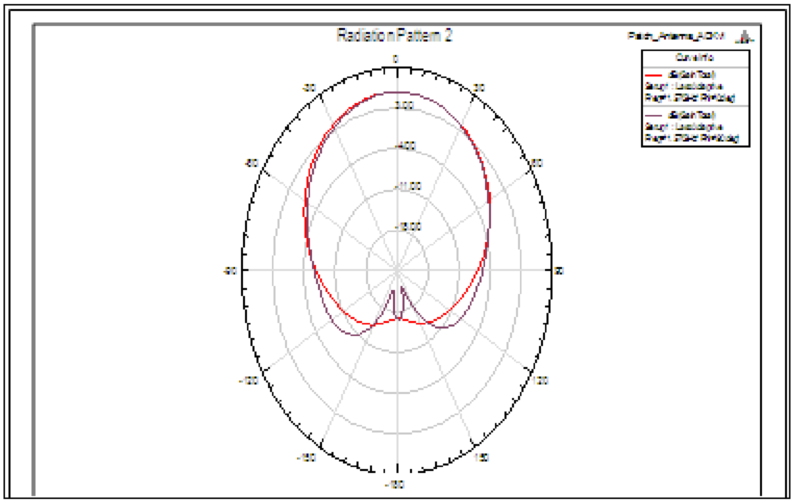

Figure 14: Gain radiation pattern for Inset-fed rectangular patch antenna

5.1 Gain comparison

Table 2 shows generated gain for rectangular and elliptical microstrip antenna array for different number of elements by using probe-fed and inset-fed.

As number of patch elements increases the total gain increases for both the arrays. However, rectangular probe-fed patch array antenna has found to be more superior than elliptical patch array interms of gain.But taking the dimension of an array into consideration there is a limit on increase of number of antenna elements.

Rectangular Patch	**Probe-fed gain**	**Inset-fed gain**
Single	4.1237	3.7989
N=2	8.2474	7.58491
N=4	16.4948	15.1698
N=8	**32.9896**	**30.3396**

Elliptical Patch	**Probe-fed gain**	**Inset-fed gain**
Single	2.89841	1.41061
N=2	5.79683	2.82122
N=4	11.5937	5.64244
N=8	23.1873	11.2849

Table 2: Gain Comparision

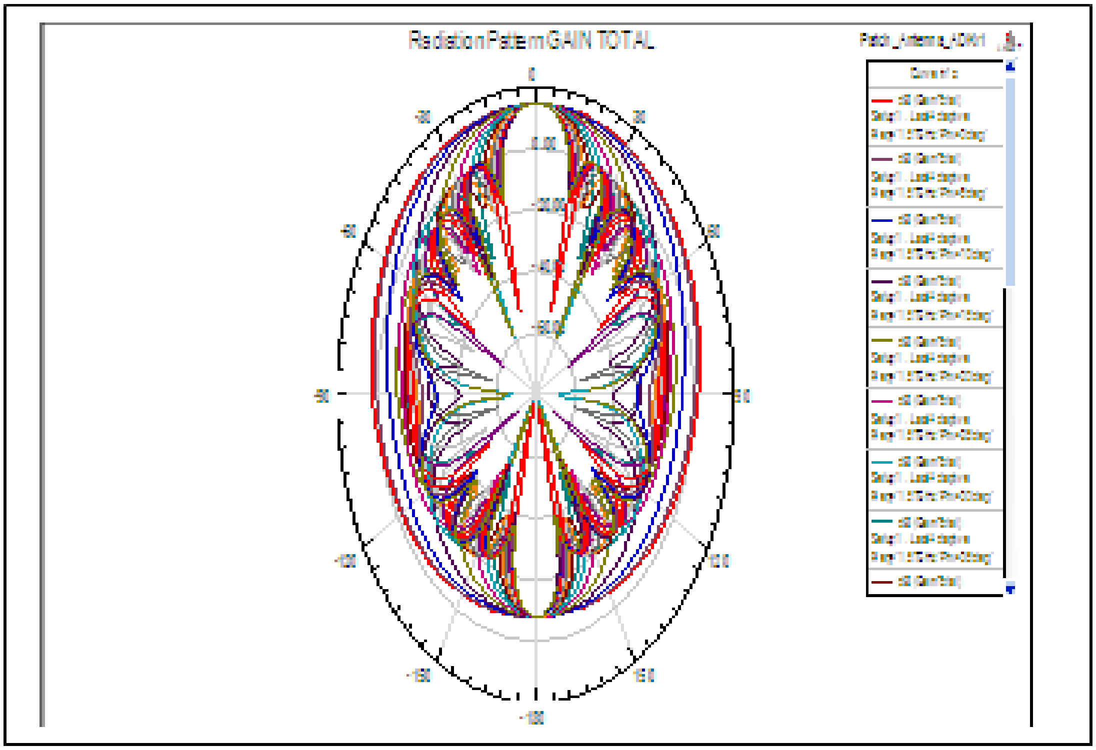

Figure 15: Gain radiation pattern for N=8 for Inset-fed rectangular patch antenna

5.2. Comparison of Directivity

Rectangular Patch	**Probe-fed gain**	**Inset-fed gain**
Single	6.0699	6.1755
N=2	12.1398	12.3298
N=4	24.2796	24.6596
N=8	**48.5592**	**49.3192**
Elliptical Patch	**Probe-fed gain**	**Inset-fed gain**
Single	4.3563	5.7927
N=2	12.1398	11.5854
N=4	17.4251	5.64244
N=8	34.8503	11.2899

Table 2:Comparision of directivity

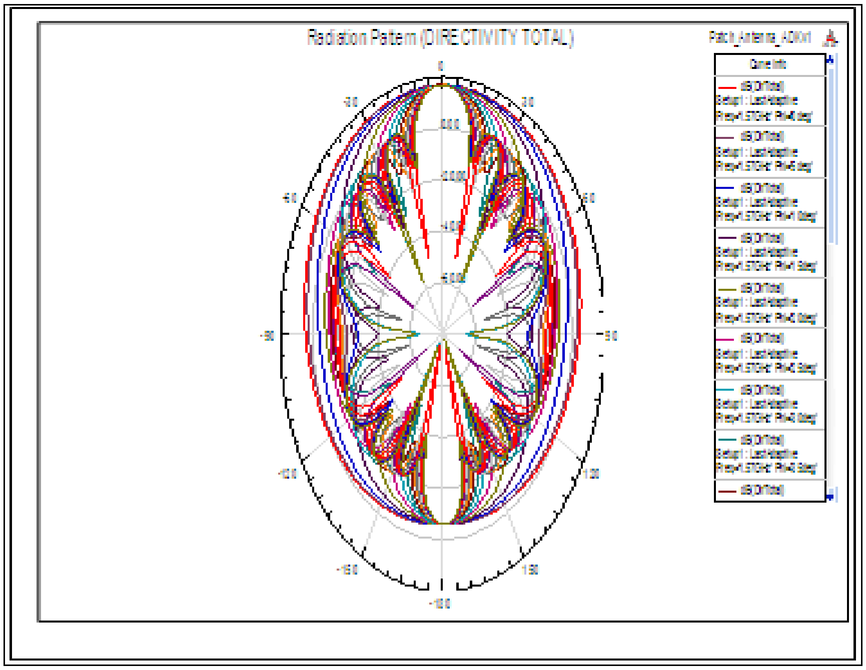

Figure 16: Directivity radiation pattern for N=8 for Inset-fed rectangular patch antenna

5.3 Comparison of Linear Vs planar arrays

Table 4 shows the obtained simulated results of directivity and gain for linear and planar arrays on Rectangular and Elliptical patch for both Probe and Inset feed antennas.Both gain and directivity, for both shapes, are decreasing from linear array to planar array. This is due to array factor which is not uniform for a planar array whereas in linear arrays the array factor is proportional to number of antennas for all observation angles which justify that gain and directivity of planar array is lower than the linear arrays [7].

	Elliptical probe- fed patch antenna		Rectangular Probe fed patch antenna	
Array	**Directivity**	**Gain**	**Directivity**	**Gain**
4 (linear)	17.4251	11.5937	24.2796	16.494
8 (linear)	34.8503	23.1873	**48.5592**	32.989
4 (planar)	16.314	10.854	22.779	15.475
8 (planar)	31.797	21.156	44.071	29.94

	Elliptical inset fed patch antenna		Rectangular Inset - fed patch antenna	
Array	**Directivity**	**Gain**	**Directivity**	**Gain**
4 (linear)	23.1709	5.64244	24.6596	15.169
8 (linear)	46.3417	11.2899	49.3192	30.339
4 (planar)	21.784	5.3047	23.139	13.726
8 (planar)	42.326	10.311	44.871	27.603

Table 4: Comparison of Gain and Directivity for Linear

5.4. Influence of element spacing

The influence of inter element distance'd' on gain radiation pattern for inset-fed rectangular patch array antenna is illustrated in Fig 18 and Fig 19. As inter element spacing increases, the beam width of the major lobes become narrower with lower level side lobes showing that the directivity of the antenna increases. However, there are limits on beam widths for a particular antenna as the side lobes become more pronounced when beam width becomes narrower.

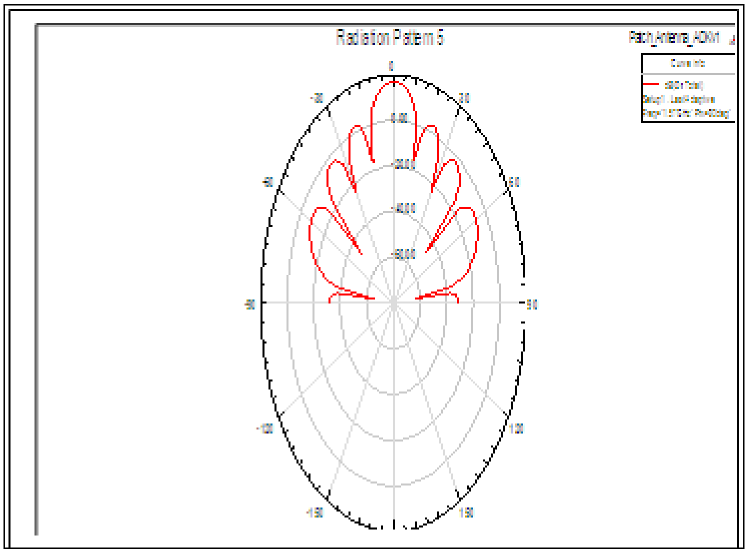

Figure 17: Radiation pattern for Inset-fed rectangular patch antenna at d=0.4 λ

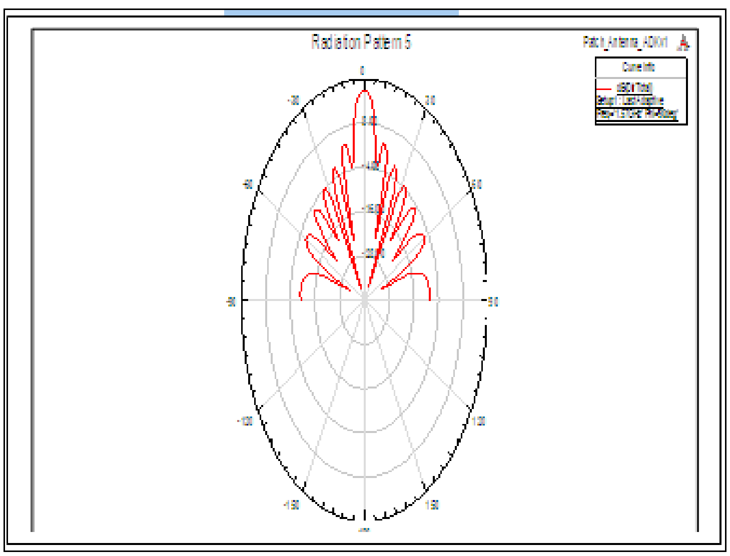

Fig .18 Radiation pattern for Inset-fed rectangular patch antenna at d=0.8λ

6. Conclusion

Multipath reception causes positioning errors in a PL augmented GPS navigation system. Hence the problem of multipath effect has been clearly defined and analyzed clearly. The design of Ceramic Inset-fed microstrip patch array antenna has been observed to be most effective to overcome multipath problem in PL augmented GPS as it provides higher gain towards LOS signals and nulls in the direction of detected PL multipath signals. Extensive simulations has been carried out to observe the antenna performance for rectangular and elliptical probe-fed as well as inset-fed array antennas by increasing the number of elements and inter-element spacing. Summarizing the results, the performance of Inset-fed rectangular patch antenna has found to be more effective by considering the antenna parameters such as VSWR, Return loss, peak realized gain and directivity. It has been also observed that, as the number of patch elements increases the gain of the antenna will also increase. Ceramic inset-fed rectangular patch array antenna (for N=8) offered an effective gain of 30.3396 and directivity of 49.3192 compared to other antennas. Finally, after analysing the effects of inter element spacing, it has been observed that the beam width of major lobe becomes narrower with increase in the inter-element spacing which allows the antenna to precisely focus towards the intended direction.

7. References

1. B.W. Parkinson and J. J. Spilker Jr., Global Positioning Systems: Theory and Applications, Volume II, 1996.
2. "http:/link.springer.com/article/10.1007" Cobb H S. "GPS Pseudolite: Theory, Design and Application", Dissertation of Doctoral Degree. Stanford: Stanford University, 1997. 87—101.
3. BILICH, A. (2012), Introduction to Multipath: Why is multipath such a problem for GNSS? http://www.gpsworld.com/tech-talk- blog/introduction-multipath-why-multipath-such-a-problem-gnss- 11328, 19 January 2008, viewed at 30/07/2012.
4. [Garg, R., 2001] Garg, R., Bhartia, P., Bahl, I., Ittipiboon, A., "Microstrip Antenna Design Handbook" Artech House, Inc. 2001.
5. C. A. Balanis, "Antenna Thoery: Analysis and Design," Wiley, New York, 1997
6. Microstrip antenna design handbook/ Ramesh G. Artech house 2001, ISBN 0-89006-513-6
7. Anouar Dalli, Lahbib Zenkouar, Seddik Bri, "Comparison of circular sector and rectangular patch antenna arrays in C-band," Journal of Electromagnetic Analysis and Applications, 2012, 4, 457-467