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Highly Directive Coaxial Line Fed Patch Antenna Array for ISM Band

Dr Monish Gupta
Electronics & Communication Engg Dept.
University institute of Engg & Technology, Kurukshetra University
Kurukshetra, India

Abstract
Patch antenna is attracting the interest of many researchers due to its characteristics like planar and conformal structure, low cost and easy to design. However, patch antenna suffers from a serious drawback of low gain. In this research a coaxial line fed patch antenna array is designed to improve the gain of antenna at ISM band of 2.4 GHz. High frequency structure simulator is used to simulate the design and to analyze the performance of patch array.
Index Terms— Patch antenna, Gain, Radiation pattern

1. Introduction

In its most basic form construction of Patch Antenna consist of a substrate on one side of which a radiating patch is fabricated while on another side ground is fabricated. Patch antenna can be fed by using a microstrip line Fig (1) or by using a coaxial line as shown in Fig (2). Radiating patch and ground are made of perfect conducting material. It is the substrate layer which dictates the performance parameters of patch antenna. Dielectric constant of the substrate, height of the substrate, length and width of the patch antenna dictates the operative frequency and performance of patch antenna.

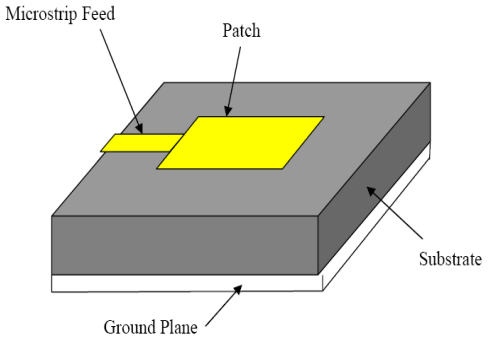

Figure 1 Rectangular Patch Antenna

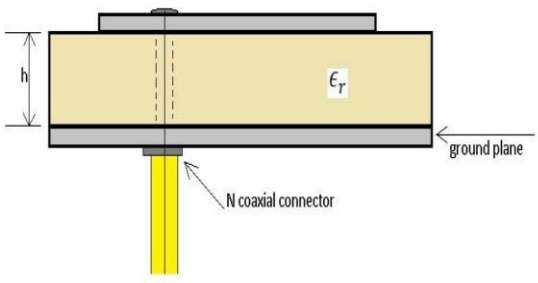

Figure 2 Coaxial fed Patch antenna

The optimized length and width of rectangular patch antenna as proposed in [1-7] is given by

$$w = \frac{C}{2f\sqrt{\frac{\epsilon_{eff}+1}{2}}} \quad ----------(1)$$

Here C is the velocity of light and ϵ_{eff} is the effective permittivity of the substrate which is given by expression

$$\varepsilon_{eff} = \frac{\varepsilon+1}{2} + \frac{\varepsilon-1}{2}\sqrt{1+12\frac{h}{w}} \quad ----------(2)$$

Here ε is the dielectric constant of substrate and h is the thickness of the substrate

The patch length is given by the expression

$$L = \frac{C}{2f\sqrt{\epsilon_{eff}}} \quad ----------(3)$$

More than one patch antenna is required to achieve gain suitable for real time devices. While designing array of antennas it is convenient to feed probe fed patch antenna array as compared to Microstrip patch antenna array. So, in this research Probe fed patch antenna array is used to improve the gain of antenna.The radiation pattern of antenna array can be calculated by multiplying the radiation pattern of single element and antenna array factor.

For N element antenna array in one dimension array factor is given by

$$AF(\theta) = \sum_{n=1}^{N} I_N e^{i\alpha} e^{(ikdcos\,\theta)} \quad ----------(5)$$

Here antenna elements are separated by distance d. I_N is the magnitude of feeding current to various elements. α Is the progressive phase shift between antenna elements. The point of observation makes angel θ with array axis and k is phase shift constant.
Enhanced beam steering and side lobe reduction can be achieved by arranging antenna elements in two dimensional arrays. When antenna elements are arranged in two-dimensional structure then array factor is given by

$$AF(\theta,\varphi) = \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} I_{mn} e^{i\alpha_{mn}} e^{(ik\,\hat{r}.\vec{r}_{mn})} \quad ---------- (6)$$

I_{mn} is the magnitude of feeding current of mn^{th} element.
$\vec{r}_{mn}$ Is the location of mn^{th} element.

$$\vec{r}_{mn} = x_{mn}\hat{x} + y_{mn}\hat{y} + z_{mn}\hat{z}$$

And

$\hat{r}$ is the location of observation point

$$\hat{r} = Sin\,\theta\,cos\,\emptyset\,\hat{x} + Sin\,\theta\,Sin\,\varphi\,\hat{y} + Cos\,\theta\,\hat{z}$$

α_{mn} is the excitation phase difference between elements.

In this research first a probe fed patch antenna is designed for 2.4 GHz by using the above-mentioned design equations.
The design parameters of patch antenna and substrate in designing Patch antenna are presented below.

Table 1 Patch antenna design parameters

S. No.	Name of Parameter	Value
1	Resonant Frequency	2.4 GHz
2	Patch Length	5 Cm
3	Patch width	4.15 cm
4	Substrate Material	Duriod
5	Substrate height	.16 cm

Structure of patch antenna and patch antenna array is simulated using High Frequency Structure Simulator.

2. Results and Discussion

The structure of coaxial line fed patch antenna designed using HFSS is shown in Fig (3).

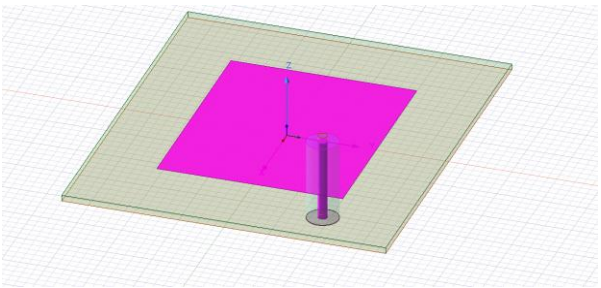

Figure 3 Coaxial fed Patch antenna

The S_{11} scattering of designed antenna are shown in Fig (4). At 2.4 GHz the value of S_{11} parameter is -2dB.

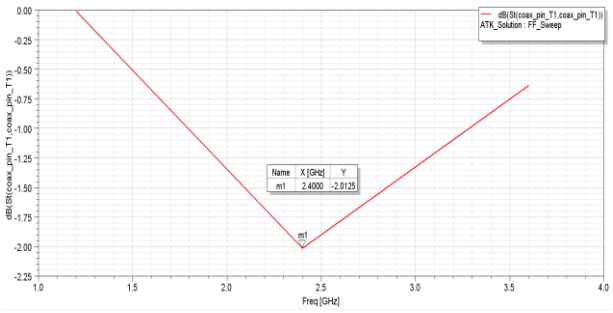

Figure 4 Coaxial fed Patch antenna

The radiation pattern of Patch antenna is shown in Fig (5). The maximum directive gain of antenna is 7.8 dB. The structure of coaxial line fed patch antenna array designed using HFSS is shown in Fig (6). The radiation pattern of Patch antenna array is shown in Fig (7). The maximum directive gain achieved is 11.66 db.

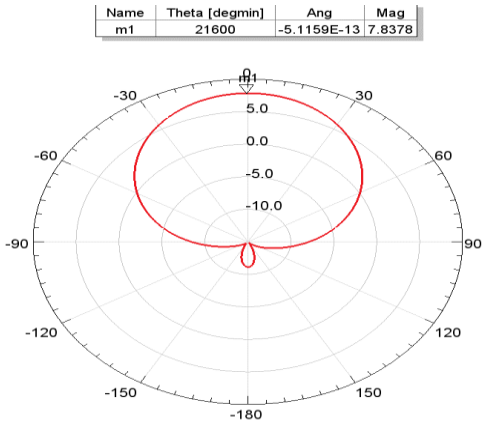

Figure 5 Radiation pattern of Coaxial fed Patch antenna

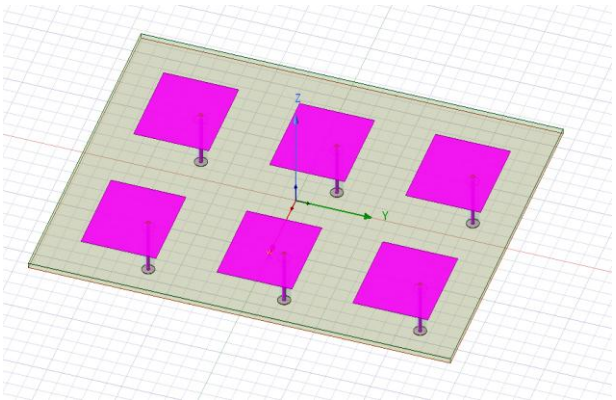

Figure 6 Coaxial fed Patch antenna array

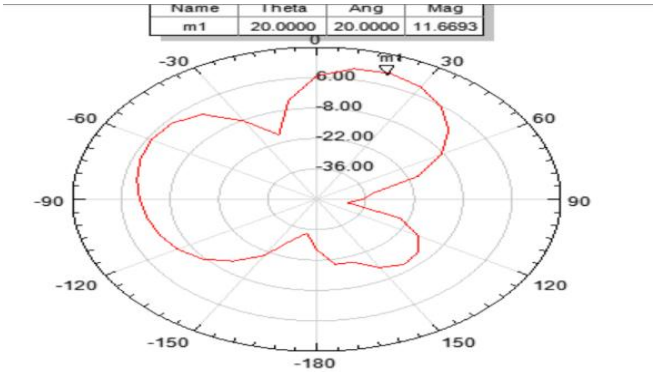

Figure 7 Radiation pattern of Coaxial fed Patch antenna

Conclusion

A highly directive patch antenna array is designed in this research. A gain of 11.66 dB is achievable from this antenna. This antenna can be effectively used in home appliances like routers for the purpose of communication.

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