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Patch Antenna Array Designed using Microstrip Lines

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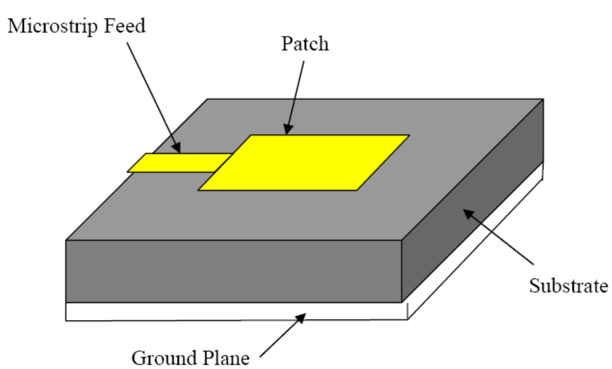
Abstract: Today microstrip patch antenna is gaining popularity in many applications due to its properties like planar and conformal structure, ease of fabricating. However microstrip patch antenna suffers from serious limitation of low band width and low gain. In this research, a design technique for enhancing gain of microstrip patch antenna for ISM band is proposed. Enhancement in gain is achieved using antenna array. While using array the most severe requirement is of impedance matching. In this work impedance matching of patch antenna array is obtained using microstrip lines. The overall gain of this antenna is achieved to be 9dB which is significant for using in application like radar systems, missiles, aeroplanes etc.
Index Terms: Patch antenna, Microstrip lines, Wilkinson power divider, Antenna array.

I. INTRODUCTION

Microstrip patch antenna is a low profile antenna which consists of radiating metallic conductor on one side of dielectric layer and metallic ground on other side of dielectric[1-4]. The most common structure of Microstrip patch antenna is as shown in Fig(1).



Fig(1) Microstrip patch antenna

Performance parameters which decide the resonant frequency of microstrip patch antenna depend on the dielectric constant and height of substrate, Length and width of patch. The width (w) of patch antenna for operative frequency (f) and substrate with dielectric constant $\varepsilon(r)$ is given by

$$w = \frac{C}{2f\sqrt{\frac{\varepsilon(r)+1}{2}}} \text{-------------(1)}$$

Here C is the velocity of light.
The effective dielectric constant of medium is given by

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

Here h is the height of substrate.

The required length of patch is given by

$$L = \frac{c}{2f\sqrt{\varepsilon\,(eff)}} - 2\Delta l \text{----------------(3)}$$

Here Δl is patch length extension and is given as

$$\frac{\Delta l}{h} = .412\,\frac{[\varepsilon\,(eff) + .3]\left[\frac{w}{h} + .264\right]}{[\varepsilon\,(eff) - .258]\left[\frac{w}{h} + .8\right]} \text{-----------(4)}$$

Microstrip patch antenna is gaining popularities these days due to its ease and low cost of manufacturing, conformal and compact structure, Dual band achievable polarization and ease in multiband operation. However microstrip patch antenna posses a series drawback of low gain. The problem of low gain in microstrip patch antenna can be overcome by using antenna arrays. In antenna arrays we can use more than one antenna to improve the gain of radiating system. Antenna elements can be connected in series(Fig 2) manner or in corporate manner(Fig 3).

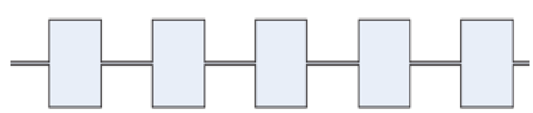


Fig (2) Series fed patch array

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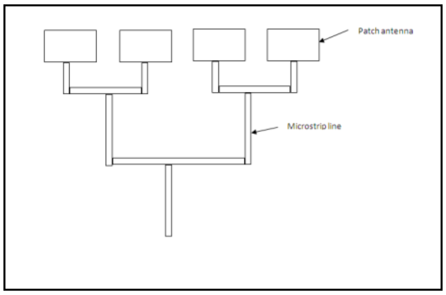

Fig (3) Corporate fed patch array

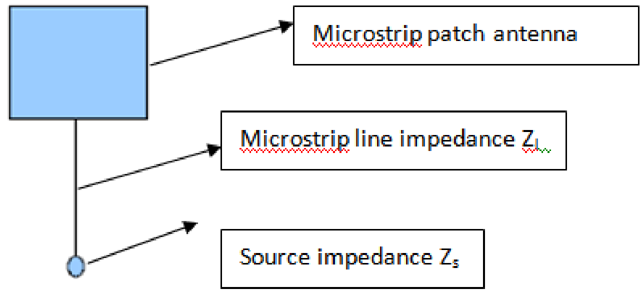

Fig (4) Patch antenna fed with source.

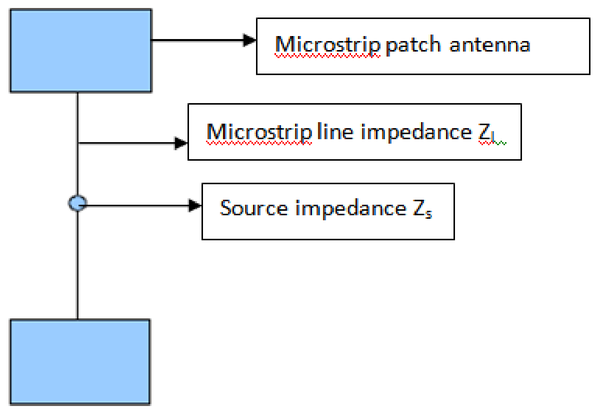

Fig (5) Patch antenna array fed with source.

In series fed microstrip antenna array one antenna element is used to feed the successive element in array. In this type of feeding methodology their exist a lot of mutual coupling between the elements hence it is very difficult to calculate the resonant frequency of the structure. Furthermore the strength of feeding signal goes on reducing as signal travels from one antenna element to successive antenna element. Due to these drawbacks this method of feeding the antenna elements is rarely used. Generally antenna array are obtained using corporate fed system. In corporate feed system all antenna elements are fed simultaneously. So the feeding strength of signal to each antenna element is almost same. Mutual coupling between the elements in corporate feed system is corporately less than series method. Furthermore the impedance matching techniques of corporate feed method is better than that of series feed method. Various feeding methods like Wilkinson power divider, Balun, feeding using N node microstrip line can be used to divide power and impedance matching technique in corporate feed patch array.

In this work a corporate fed patch antenna array of two elements is designed using microstrip lines. Matching of characteristics impedance of microstrip line with source is required for the purpose of transferring maximum amount of power from source to antenna. The width of microstrip line decided the characteristics impedance of lines. So by varying the width of microstrip line a desired value of characteristics impedance of line can be obtained. For the purpose of matching the characteristic impedance of microstrip line should be equal to n times the impedance of the source. Here n is the number of twigs emerging from the source. So for source impedance of Z_s the impedance of microstrip line required for the purpose of matching is $Z_l = n Z_s$.

So for the structure shown in Fig (4) impedance of microstrip line required is $Z_l = Z_s$(source impedance). For the structure shown in Fig(5) required $Z_l = 2Z_s$

II. Results and Discussion

By using above mentioned equations the dimensions of patch antenna derived are as given in Table (1).

Table 1

Resonant frequency	2.4 GHz
Substrate	Rogers RT / duriod 58809(tm)
Dielectric Constant	2.2
Substrate Height	0.787 mm
Patch Length	41.7 mm
Patch Width	47.93 mm
Conductor Thickness	0.05 mm

The dimensions of microstrip line used for obtaining 50 ohm characteristics impedance are given in Table 2.

Table 2

Resonant frequency	2.4 GHz
Substrate	Rogers RT / duriod 58809(tm)
Dielectric Constant	2.2
Substrate Height	0.787 mm
Length of microstrip line	8 mm
Width of microstrip line	2.46 mm
Conductor Thickness	0.05 mm

The structure of Microstrip patch antenna obtained using HFSS is represented in Fig (6).

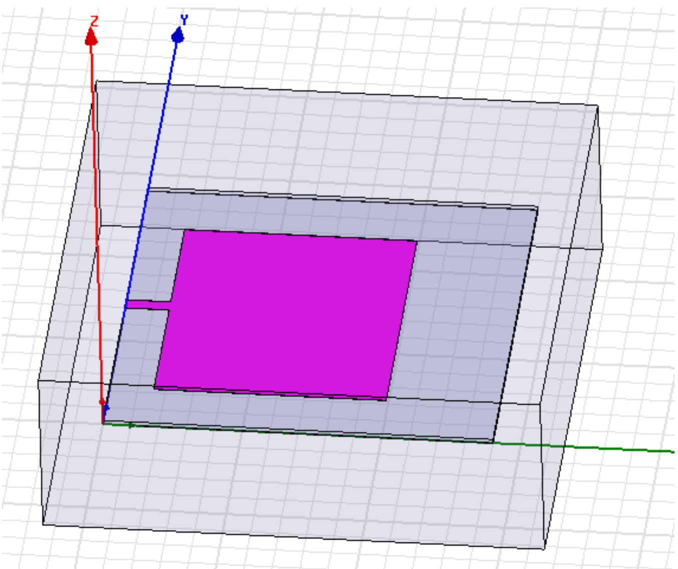

Fig (6) Microstrip patch antenna using HFSS

The polar radiation pattern of gain for this structure is as shown in fig (7)

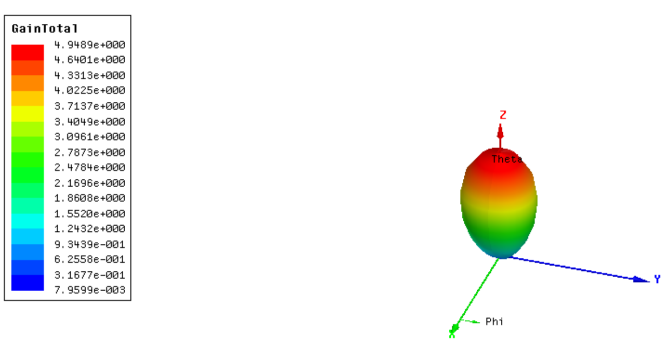

Fig (7) Polar radiation pattern

The radiation pattern for this antenna is plotted in fig(8)

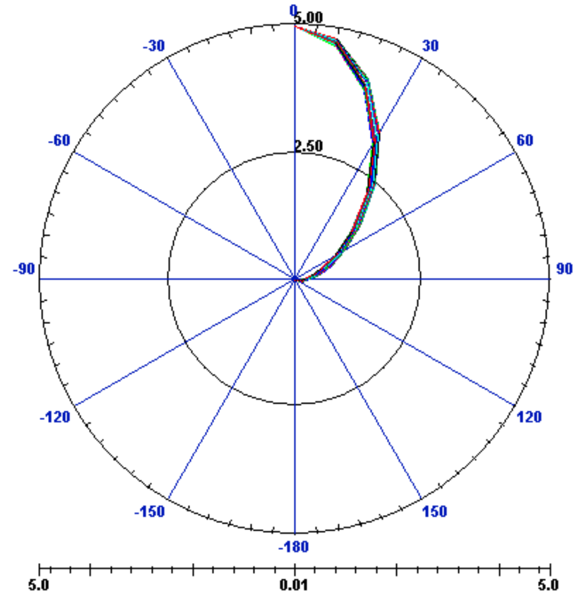

Fig (8) Radiation pattern of patch antenna

The maximum directive gain for this structure comes out to be 6.9 dB.

A two element patch array using microstrip line designed using HFSS is as shown in fig(9).

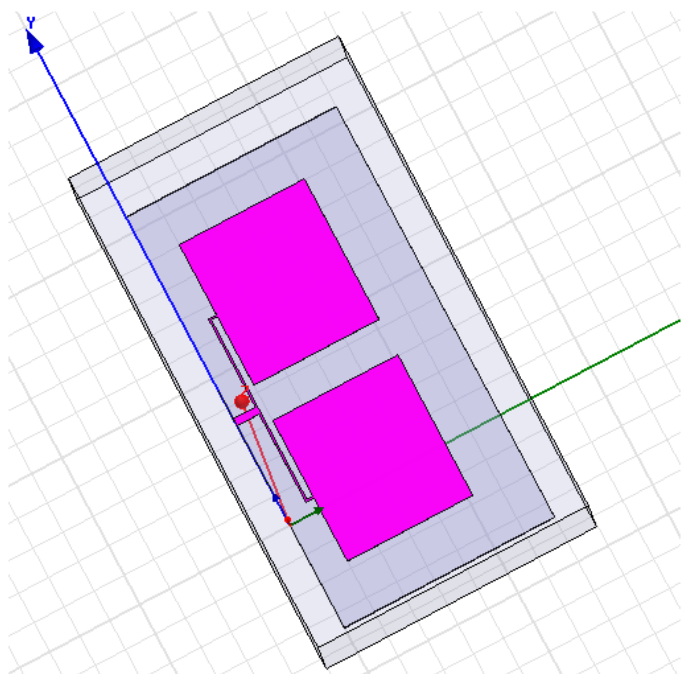

Fig (9) Microstrip patch antenna array using HFSS

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Dimensions of microstrip line for characteristics impedance of 100 ohm are given in Table (3).

Table 3

Resonant frequency	2.4 GHz
Substrate	Rogers RT / duriod 58809(tm)
Dielectric Constant	2.2
Substrate Height	0.787 mm
Length of microstrip line	32 mm
Width of microstrip line	.65 mm
Conductor Thickness	0.05 mm

The scattering parameters obtained for this structure are as shown in fig(10).

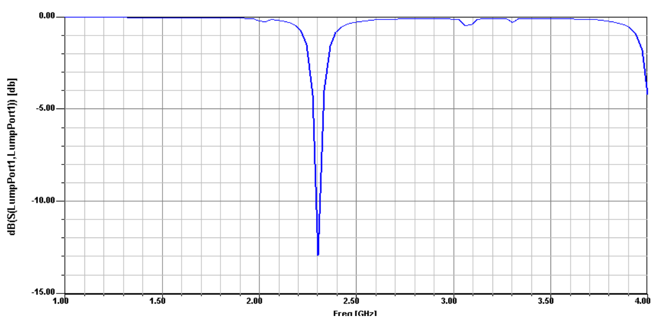

Fig (10) S- parameters of Microstrip patch antenna array

The polar radiation pattern of gain for this structure is as shown in fig(11)

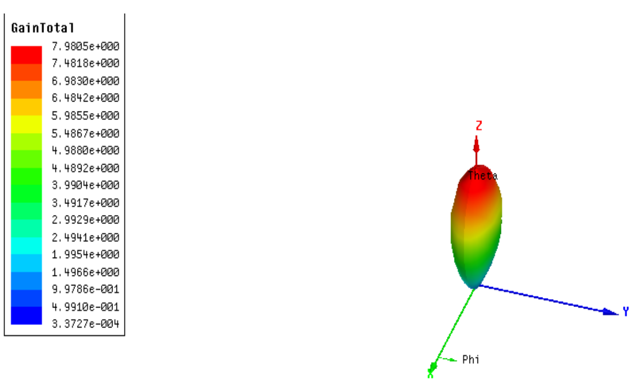

Fig (11) Polar radiation pattern

The radiation pattern for this antenna is plotted in fig (12)

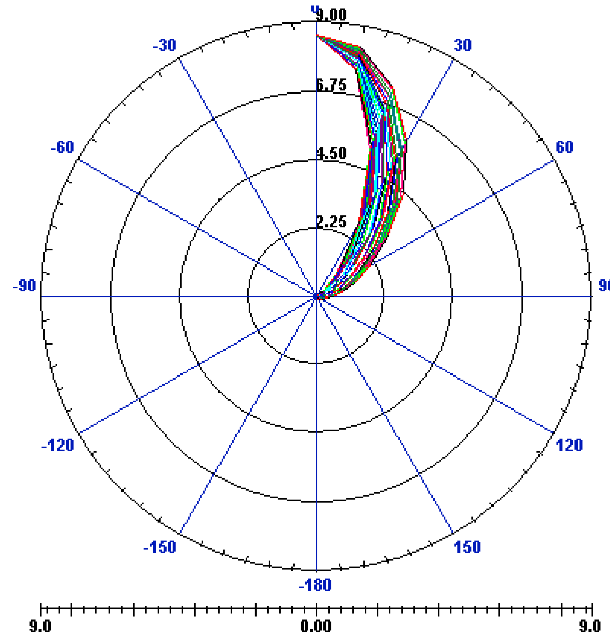

Fig (12) Radiation pattern of patch antenna array

The maximum directive gain for this structure comes out to be 9.02 dB.

III. Conclusion

A two element microstrip patch antenna array is designed using microstrip line. The gain of array had been improved by a factor of 2.1dB. gain of the system can further be improved by increasing the number of elements in the array.

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