Design of Microstrip Patch Antenna Array using Parasitic Coupling

T.Balakumaran
Assistant professor
Department of Electronics and Communication Engineering
Coimbatore Institute of Technology

D.Sasidharan
PG Scholar
Department of Electronics and Communication Engineering
Coimbatore Institute of Technology

ABSTRACT
The parasitic coupling is an inevitable phenomenon in multiband patch antenna for reducing the antenna size. Traditionally, a multiband microstrip patch antenna is fed directly through a direct feed network such as T-junction and quarter wave transformer. In this project, a new parasitic coupled feeding to be proposed for simplifying the geometry of an antenna. A four element microstrip array (5.2 GHz to 5.5GHz) to be designed, fabricated and tested. The radiation characteristic of feeding to be simulated using HFSS software.

Keywords
Multiband microstrip, direct feeding, parasitic feeding, HFSS, Quarter wave transformer.

1. INTRODUCTION
Microstrip antennas are widely used in wireless communication systems because of their easy fabrication, small size, less weight and low cost. The gain of the antenna can be increased when the array of patches is used. A patch antenna is fabricated by etching the antenna element in metal layer on dielectric substrate, opposite side of which forms a ground plane. The patches can be in the shape of rectangular, circular, triangular etc. Due to smaller size, microstrip antennas are used in wide range of frequencies and low manufacturing tolerances. As the size is less and cheap to fabricate, it can be used in military and aircraft application. The radiating element is excited by two methods direct feeding and parasitically coupled feeding. In direct feed, Microstrip patch is fed directly through a corporate feed network using T-junction and quarter wave transformers. In parasitically coupled feeding, the microstrip patch is excited through capacitive gap. The parasitically coupled feeding reduces the size further compare to the direct feeding.

Tikriti et.al designed a microstrip antenna for 60 GHz application using small lens [1].The microstrip antenna achieves a gain of 10 dB, but by using the egg-cup shaped lens, the gain increases to 15dB.

S eki ×et.al developed an antenna, in this antenna the multilayer parasitic microstrip antenna for 60 GHz and achieved the antenna gain of 11.1dB with antenna size of 10mm 10mm [2].

Farsi et.al used Mutual coupling has a direct impact on the performance of multiple-input-multiple-output (MIMO) and antenna array systems [3]. This interaction between elements degrades the system performance in two ways, namely by increasing S_{12} and by distorting the radiation pattern. This problem mainly arise when the antennas are close to each other. In this antenna size is reduced by mutual coupling and this can be achieved by U-shaped microstrip antenna.

Limitation of this method is U‟ shaped microstrip antenna occupies some area so antenna size is not much more reduced.

Lutheret.al proposed the single input two layer and three element array with 1 GHz using varactor diode [4] the varactor diode is used to maintain the resonance at 1 GHz and control the mutual coupling. The varactor diode used to reduce mutual coupling it is economically fabricated antenna. But the disadvantage of their method is using the varactor diode achieved low gain and bandwidth. The proposed method of multiband antenna increases the gain and bandwidth using mutual coupling.

2. MICROSTRIP PATCH ANTENNA
The radiating patch is kept at one side of the microstrip patch antenna and the ground plane at other side. The patch is made up of any conducting material such as copper or gold and it may be of any shape such as, circular, triangular, rectangular, square and elliptical. On the dielectric substrate, the radiating patch and feed lines is photo etched.

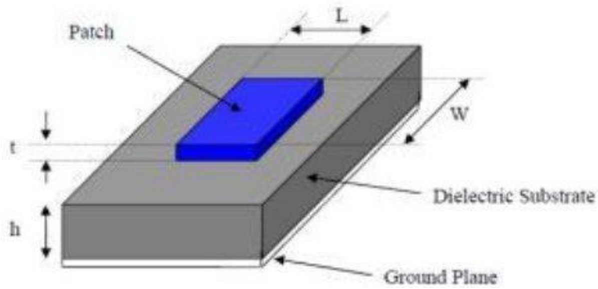


Fig.1. Structure of a Microstrip Patch Antenna

The increased antenna gain is achieved by using the array of patches. In general, the radiation pattern is so wide and directivity is very low. High directive beam is required, when this antenna is used in remote sensing application so, the array of patches is combined with the antenna to increase the radiation pattern and directive beam. In microstrip arrays, the mutual coupling is present in between the antenna elements. Here, the edge of the microstrip patch is directly connected to the conducting strip of the feed. The width of the conducting strip is smaller compared to the patch which has the advantage of providing planar structure when the feed is etched with the same substrate.

Microstrip patch antennas radiates due to the fringing effects present in between the ground plane and the patch edge. The dielectric material with larger thickness and low dielectric constant is chosen for better efficiency, increased radiation performance and bandwidth. However, these configuration leads to a larger antenna size so that, a trade-off must be realized between the antenna performance and antenna dimensions.

2.1 Design of microstrip patch antenna

Width, height and length of patch antenna can be calculated by using following equation.

$$W = \frac{c_o}{2 f_r}\sqrt{\frac{2}{e_r + 1}} \quad \text{------------------} \quad (2.1)$$

Where W is the width of the patch£ element, fr is the resonance frequency of the antenna to be designed and is the relative dielectric constant of the substrate. The effective dielectric constant is lower than the relative dielectric constant because a portion of the fields are in air above the substrate. Effective dielectric constant can be calculated by the Eq. (2.2).

$$e_{reff} = \frac{e_r + 1}{2} + \frac{e_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \quad (2.2)$$

Where h is the height of the substrate and Patch height should be in the range of 0.003λ to 0.05λ.

Patch Length can be calculated by Eq. (2.3)

$$L = \frac{c_o}{2 f_r \sqrt{e_{reff}}} - 2\Delta L \quad \text{------------------------------} \quad (2.3)$$

Where Length is in between λ/3 to λ/2, and is the additional length extension.

Effective Patch Length can be calculated using Eq.(2.4)

$$L_{eff} = L + 2\Delta L \quad \text{----------------} \quad (2.4)$$

In our method we have chosen dielectric substrate is RT-Duroid. Dielectric constant of (e_r) of material is 2.2.

Table 1: Measurement of antenna parameters

S.NO	PARAMETERS	RT-DUROID(∈ =2.2)			
		5.2 GHz	5.3 GHz	5.4GHZ	5.5 GHz
1	Width W"	2.280	2.237	2.196	2.156
2	Height	2.884	2.830	2.777	2.727
3	Effective dielectric constant (e_{reff})	2.159	2.159	2.159	2.159
4	Patch length	1.932	1.896	1.861	1.827

The measurement (width, height,Ɛ length) of apatch antenna with frequencies of 5.2 GHz to 5.5 GHz by using material RT- Duroid (=2.2)were calculated.

3. DIRECT FEED

A Microstrip array is fed directly through a corporate feed network using T-junction and quarter wave transformers. The feed network for this antenna consumes a large space in comparison with the size of the radiating elements. If the feed network is eliminated in this design, much space can be saved and the ohmic losses corresponding to the feed network can be reduced.

T-junction are reciprocal and can be considered lossless if transmission line loss is not taken in to account. A lossless T-junction can be modelled as a junction of three transmission lines. Lossless T-junction is not matched at all ports and it has no isolation between output ports.

Quarter wave transformer is the effective method for impedance matching of load to the transmission line and wide band matching can be done using multi band transformer. It is similar to have a stub having the length of quarter of the wavelength. The end of a transmission line with characteristic impedance Z_o is terminated with a resistive load. Unless $R_l = Z_0$, the resistor is mismatched to the line, and thus some of the incident power will be reflected. Correct the situation by placing a matching network between the line and the load.

4. PROPOSED PARASITICALLY COUPLLING

The electromagnetic interaction between the antenna elements in an antenna array is called mutual coupling. Mutual coupling exhibits differently in transmitting and receiving antenna arrays and has to be treated differently. The effect of mutual coupling is serious if the element spacing is small. It will affect the antenna array, mainly it changes the array radiation pattern, and matching characteristics of the antenna elements.

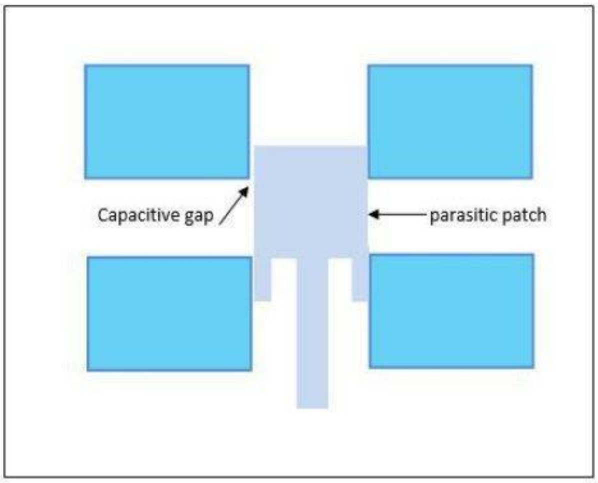


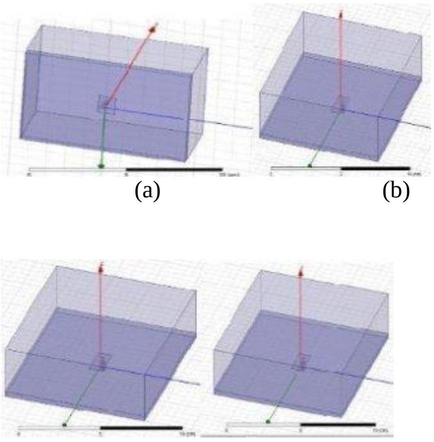
Fig 2.Proposed parasitically fed array

The patch elements in this design are not attached to the microstrip feed but are excited through a capacitive gap. The performance of the parasitically fed array is compared with that of the array antenna fed by T-junctions and quarter-wave transformers. In the analysis, the antenna is characterized by impedance matching, antenna gain, and radiation pattern and efficiency. We propose parasitically coupled antenna elements that eliminate the feed network and simplify the design and fabrication. Antenna patches without a direct feed structure are common and are referred to as parasitic patches. For instance, we specifically consider radiation in the broadside direction for the parasitically coupled array. The goals are to investigate if this new design has any potential and to compare its performance with that of traditional direct fed structures that use T-junctions and quarter-wave transformers.

The direct feed network for the microstrip array is simplified using the proposed parasitically coupled feed. The proposed four-element parasitically coupled micro-strip patch array is shown in Fig.2. the advantage of this feeding method is more significant when the width of the microstrip line is thicker and consumes more space. Design the multiband microstrip patch using direct feed and Parasitic feed and finally compare the both results with gain, bandwidth and radiation characteristic. The gain of the antenna to be increased by using Electro Magnetic Compatibility(EMC).We have a designed multiband antenna in direct feed and parasitic coupling by using HFSS software.

5. PATCH ANTENNA MODEL

In this method coaxial feeding is used to excite the antenna. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation.



(a) (b)

(c) (d)

Fig 3. Simulation of Patch Antenna (a)5.2Ghz (b) 5.2Ghz (c) 5.4Ghz (d) 5.5Ghz

The fig.3 shows the patch antenna model for5.2Ghz, 5.3Ghz, 5.4Ghz and 5.5Ghz respectively.

6. RESULTS AND DISCUSSION

The multiband microstrip patch using direct feed antenna is simulated using Ansoft HFSSv13.0. Reflection coefficient, radiation patterns and 3D polar plot were analyzed.

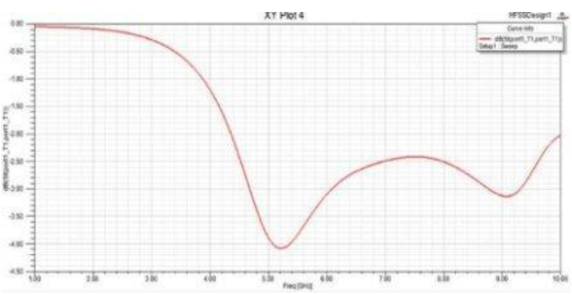


Fig.4. Return loss

Return loss is a process of measuring the effective power delivery from the transmission line to the antenna. From fig.4, it clearly shows that the return loss is minimum for designed frequency 5.2GHz.

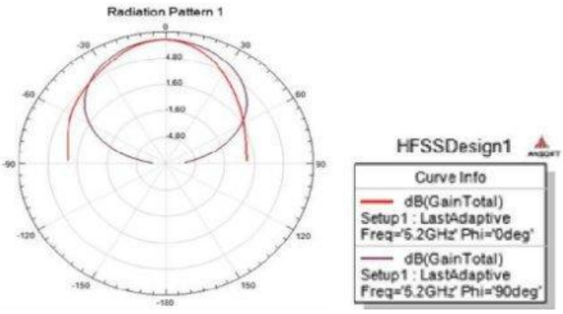


Fig.5 Radiation pattern

Fig.5 shows the 2D gain radiation pattern for the designed antenna at Ø=90deg and Ø=0deg. At frequency 5.2Ghz with the maximum value around 5dB.

The radiation pattern refers to the signal strength from the antenna or other sources from Fig.5, the pattern which has high signal strength (i.e.) the pattern with 5.2GHZ is said to be maximum (or) main lobe. The other patterns or lobes said to be a side lobes which is used to represent the radiation in unwanted directions.

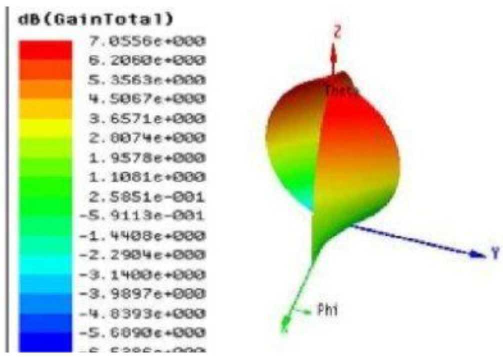


Fig.6 3D Polar plot

Fig.6 shows 3D polar plot of the designed antenna in broadside radiation. The max value of 7.0556dB is obtained in Z (broad side direction).

7. CONCLUSION

The direct feed is designed and its return loss, radiation pattern and its 3D polar plot is determined. The return loss is found to be minimum, whereas the radiation pattern is maximum and high gain is achieved through the 3D polar plot for the designed frequency (5.2-5.5GHz). The parasitic feed has to be designed and its bandwidth, gain, and the radiation characteristics are to be compared with the direct feed. Thereby the antenna size may be reduced using proposed parasitically coupled feeding method.

8. REFERENCES

[1] M. Al-Tikriti, S. Koch, and M. Uno, A compact broadband stacked microstrip array antenna using eggcup-type of lens, IEEE Microw.Wireless Compon. Lett, vol. 16, no. 4, pp. 230 232, Apr. 2006.

[2] T. Seki, N. Honma, K. Nishikawa, and K. Tsunekawa, Millimeterwave high-efficiency multilayer parasitic microstrip antenna array on Teflon substrate, IEEE Trans. Microwave. Theory Tech., vol. 53, no. 6, pp. 2101 2106, June 2005.

[3] S. Farsi, H. Aliakbarian, D. Schreurs, B. Nauwelaers, and G. A. E. Vandenbosch, Mutual coupling reduction between planar antennas by using a simple microstrip U-section, IEEE Antennas WirelessPropag.Lett., vol. 11, pp. 1501 1503, Dec. 2012.

[4] J. J. Luther, S. Ebadi, and X. Gong, A microstrip patch electronically steerable parasitic array radiator (ESPAR) antenna with reactance-tuned coupling and maintained resonance, IEEE Trans.Antennas Propag., vol. 60, no. 4, pp. 1803 1813, Apr. 2012

[5] T. Seki, N. Honma, K. Nishikawa, and K. Tsunekawa, A 60-GHz multilayer parasitic microstrip array antenna on LTCC substrate for system-on-package, IEEE Microw. Wireless Compon. Lett., vol. 15, no. 5, pp. 339 341, May 2005.

[6] K. H. Badr, Design, fabrication, and measurement of four by-four planar antenna sub-array, inProc. 2nd Int. Conf. on Adaptive Scienceand Technology, 2009, pp. 396 401.

[7] K.-S. Chin, H.-T. Chang, J.-A. Liu, H.-C. Chiu, J. S. Fu, and S.-H. Chao, 28-GHz patch antenna arrays with PCB and LTCC substrates, in Proc. Cross Strait Quad Regional Radio Science and Wireless Technology Conf., , pp. 355 358,Jul. 26 30, 2011

[8] X.-S. Yang, B.-Z. Wang, S. H. Yeung, Q. Xue, and K. F. Man, Circularly polarized reconfigurable crossed-Yagi patch antenna, IEEE Antennas Propag. Mag., vol. 53, no. 5, pp. 65 80, 2011.

[9] Y. R. Samii and E. Michielssen, Electromagnetic Optimization by Genetic Algorithms. New York, NY, USA: Wiley, 1999.

[10] K. Deb, A. Pratap, S. Agrawal, and T. Meyarivan, A fast and elitist multiobjective genetic algorithm: NSGA-II, IEEE Trans. Evol.Comput., vol. 6, pp. 182 197, Apr. 2002.

[11] S.H.Yeung,W. S.Chan, K. T. Ng, andK. F. Man, Computational optimization algorithms for antennas and RF/microwave circuit designs: An overview, IEEE Trans. Ind. Inf., vol. 8, no. 2, pp. 216 227, May 2012.

[12] S. H. Yeung, K. F. Man, K. M. Luk, and C. H. Chan, A trapeizform U-slot folded patch feed antenna design optimized with jumping genes evolutionary algorithm, IEEE Trans. Antennas Propag., vol. 56, no. 2, pp. 571 577, Feb. 2008.