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International Journal of Engineering Research in Electronic and Communication Engineering (IJERECE) Vol 3, Issue 5, May 2016

Analysis of Mutual Coupling effect in Micro Strip antenna arrays using IE3D

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Abstract: **In this paper, effect of mutual coupling on the performance of micro strip antenna array is analyzed using IE3D simulation tool. Array is designed using rectangular micro strip antennas to operate at frequency 2.45GHz. Strength of the mutual coupling is measured by extracting parameter S21. It is observed from the simulations that gain of the array reduces as the mutual coupling increases. As the distance between antenna increases mutual coupling reduces but side lobe level increases.**

***Index Terms*— Micro strip antenna, Mutual coupling, Inset feed, Return Loss, Radiation Pattern**

I. INTRODUCTION

For effective wireless communication, the strength of signals at transmitting and receiving side should be more. Antenna array [1] [2] is one technique which improves the gain of antenna systems. But there will be mutual coupling between elements in arrays which affects the performance and efficiency of antenna array system. In micro strip antennas, radiation occurs due to the electromagnetic leakage from the antenna edges [3] [4]. When two antennas are near each other, whether one or both are transmitting or receiving, part of the energy which is primarily intended for one antenna ends up at the other antenna. The amount depends primarily on the radiation i) characteristics of each element ii) relative separation between array elements iii) relative orientation of each element.

In micro strip antenna arrays, mutual coupling [5] [6] is primarily attributed to the fields that exist along the air-dielectric interface. The fields can be decomposed into space, surface and leaky waves. To obtain high radiation efficiency and wide bandwidth, substrate having low permittivity and thick profile is extensively used in design of micro strip antenna. However, a common disadvantage of micro strip antennas is surface waves, which exist whenever the substrate has a dielectric constant ε_r is greater than one. Surface waves are guided by air-dielectric interface and propagate within the substrate. Surface waves contribute to one adverse effect in micro strip antenna arrays that is mutual coupling between elements of array. In antenna array, the mutual coupling effect will depreciate the radiation properties of the array. To reduce surface waves in a micro strip substrate, numerous studies have been carried out including electromagnetic band gap (EBG) structures. The coupling for two side-by-side micro strip patch elements is a function of the relative alignment. When these elements are placed collinearly along E-plane, the coupling referred as E-plane coupling. For an edge-to-edge separation, the E-plane exhibits the smallest amount of coupling for very small spacing.

In this paper, micro strip antenna array of two elements is designed and analyzed using IE3D simulation tool. Effect of mutual coupling on antenna pattern and gain is studied by varying distance between antennas.

II. DESIGN OF ANTENNA ARRAY

Element of the array is first designed to operate at desired frequency then the number of elements in array is chosen depending on the gain required. Antenna is design to operate at frequency *fo* using substrate with thickness h, permittivity ε_r, and loss tangent tan δ. Width *W* and length *L* of the micro strip rectangular antenna, effective permittivity ε_{reff}, effective length Leff and increase in patch length ΔL(Figure 1) due to fringing effect are given in equations (1) - (6) [5].

$$W = \frac{c}{2f_o}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

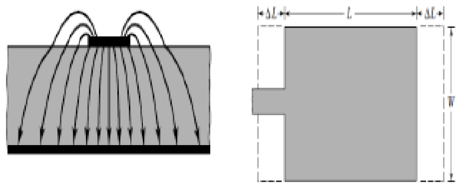


Figure 1: Fringing Effect at edges of Patch

Effective Dielectric constant:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (2)$$

Patch Length:

$$L = L_{eff} - 2\Delta L \quad (3)$$

Effective Length:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad (4)$$

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (5)$$

Inset Length [7]:

$$y_o = 0.5 * L * 10^{-4}\{0.001699\varepsilon_r^7 + 0.13761 - 6.178\varepsilon_r^5 + 93.187\varepsilon_r^4 - 682.69\varepsilon_r^3 + 2561.9\varepsilon_r^2 - 4043\varepsilon_r + 6697\} \quad (6)$$

Inset Width: wo=3*W50□ here, W50□ is Width of 50□ Transmission Line.

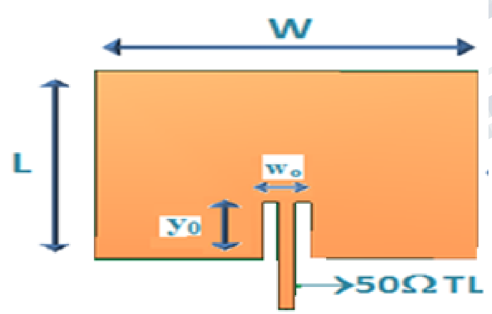


Figure 2: IE3D design of Single antenna

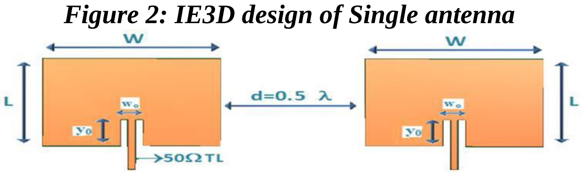


Figure 3: IE3D design of two antenna array

In this work, antenna is designed to operate at 2.5GHz using FR4 material with dielectric constant □r=4.3, loss tangent tan□=0.025 and thickness h=0.8mm. Dimensions of the antenna to operate at 2.5GHz are patch width *W*=36.857mm and patch length *L*=29.56mm. Inset length and width are *yo*=8.87mm, *wo*= 4.52mm.

Characteristic impedance of the feed line is taken Zo =50□, width and length of the feed lines are W50□= 1.5 mm and Length L50□=16.75mm.

Inset-fed patch antenna and array of two elements are shown in Figures 2 and Figure 3 respectively. Coupling between the antennas in the E-plane is studied for different values of d as shown in Figure 3.

III. SIMULATION RESULTS

The Return loss S11 for two element array for different „d" values is shown in Figure 4. Return Loss does not vary with respect to the distance between the antennas.

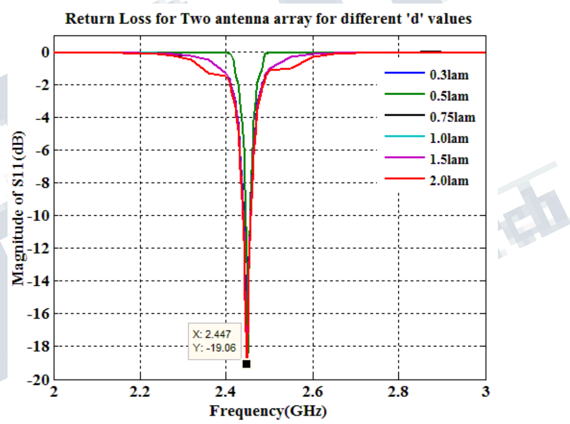


Figure 4: Return Loss for two antenna array for different „d" values

The mutual coupling S12 in dB between two antennas in the array for different values of d from 0.35□ to 2□ in steps are shown in Figure 5.At resonant frequency fo=2.45GHz, the coupling values are marked.

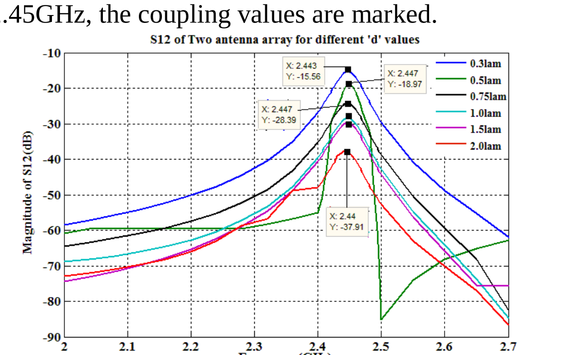
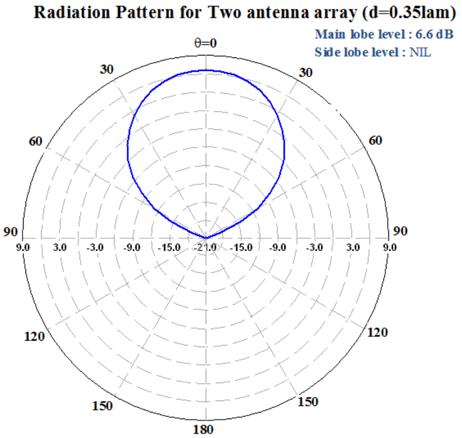


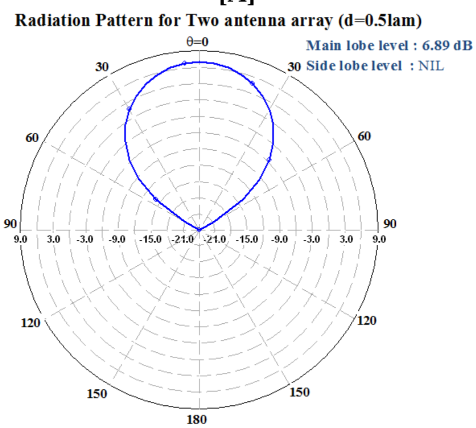
Figure 5: Coupling in two antenna array for different „d" values

The Radiation pattern for two antenna array at resonant frequency fo=2.45GHz for variation of distance between elements from 0.35□ to 2□ are shown in Figure 6 (a) to 6 (f) respectively. For the values 0.35□ and 0.5□

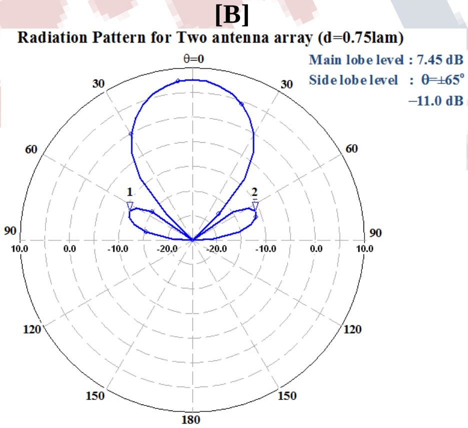
there will be no sidelobes and as the distance between elements increases greater than 0.5λ, the sidelobes occurs.



[A]



[B]



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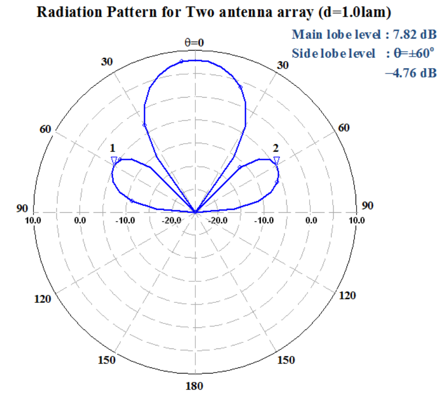

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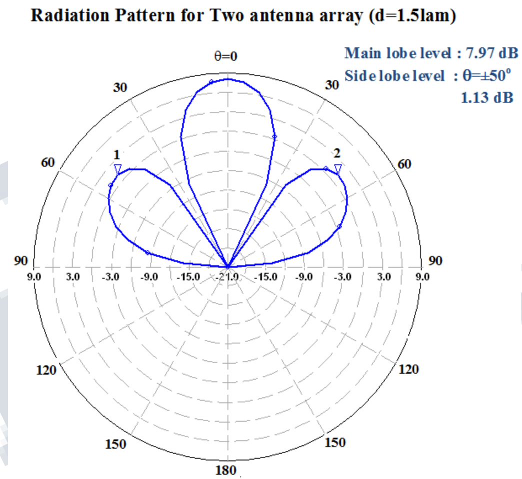

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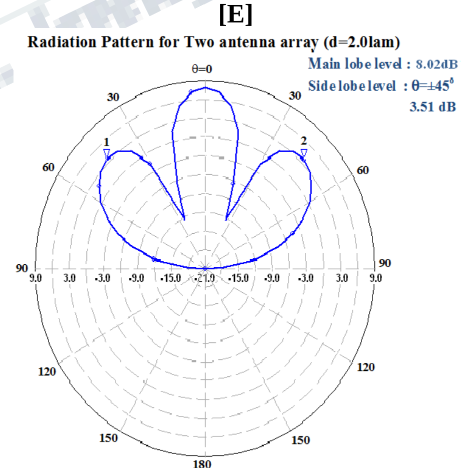

[F]

Figure 6: Radiation Pattern of two antenna array a) 0.35λ b) 0.5λ c) 0.75λ d) 1.0λ e) 1.5λ f) 2λ

TABLE I: Comparison of Results

Distance between elements(mm)	S_{12} (dB) at f_o	Main lobe Level(dB)	Side lobe Level(dB)
0.35λ	-15.5	6.6	----
0.5λ	-18.7	6.89	----
0.75λ	-24.3	7.45	-11
1.0λ	-28.3	7.82	-4.76
1.5λ	-29.7	7.97	1.13
2.0λ	-37.8	8.02	3.5

Comparison of Coupling values and Radiation Pattern in two antenna array as distance between elements increases is as shown in Table I. Coupling level S12 decreases as distance increases which also reduce the mutual coupling effect in array.

In radiation pattern, it can be seen that Main Lobe level changes slightly but there is a noticeable changes in Side lobe level i.e, side lobe level increases drastically with respect to increase in distance between elements and it also becomes positive for distance greater than 1.0□.

Gain versus frequency for two antenna array for variation of distance between elements is shown in Figure 7. Gain of antenna array increases as the distance between elements increase. Here, two antenna array reads a maximum value of 8.02dB at 2.45GHz for d=2□ due to the low mutual coupling effect as distance is more.

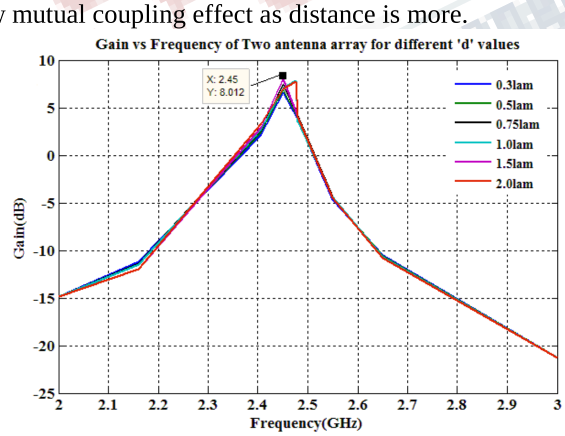

Figure 7: Gain vs. Frequency of two antenna array for different „d" values

IV. CONCLUSION

From this parametric study of mutual coupling effect, it is concluded that as the distance between elements increases coupling effect reduces and performance of array improves. But if the distance is increased to higher value, the size of antenna increases and side lobe level increases. Thus, there is a tradeoff between size and coupling effect in arrays. Therefore, distance between elements must be set at an optimized value based on the application requirements such that performance is not much affected and size is smaller enough.

REFERENCES

[1] T.Gunasekaran, N.Veluthambi, P.Ganeshkumar, K.R. Shankar Kumar "Design of Edge Fed Micro strip Patch Array Antenna Configurations for WiMAX", IEEE International Conference on Computational Intelligence and Computing Research,2013.

[2] Randy Haupt and Yahya Rahmat Samii," Antenna Array Developments: A Perspective on the Past, Present and Future" IEEE Antennas and Propagation Magazine, Vol. 57, No. 1, February 2015.

[3] David M. Pozar, "Micro strip Antennas", Proceedings of the IEEE, vol. 80, No. 1, January 1992.

[4] Pallavi Singhal and Kuldeep Jaimini "Rectangular Micro strip Patch Antenna Design using IE3D Simulator" International Journal of Current Engineering and Technology, Vol.4, No.2 ,April 2014.

[5] C. A. Balanis, "Antenna Theory, Analysis and Design", John wiley & sons, inc, New York 1997.

[6] Hema Singh, H. L. Sneha and R. M. Jha, "Mutual Coupling in Phased Arrays", International Journal of Antennas and Propagation Volume 2013.

[7] M. Ramesh and YIP KB "Design Formula for Inset Fed Micro strip Patch Antenna" Journal of Microwaves and Optoelectronics, Vol. 3, N.o 3, December 2003.