

# Triangular Patch Antennas for Dual Mode 802.11a,b WLAN Application

Raul R. Ramirez and Franco De Flaviis  
Department of Electrical and Computer Engineering  
University of California, Irvine, USA  
[ramirez@ece.uci.edu](mailto:ramirez@ece.uci.edu), [franco@uci.edu](mailto:franco@uci.edu)

**Abstract**—The analysis of equiangular triangular patch antennas is conducted to determine the mutual coupling under the constraint of small interelement spacing. The results show that the optimum location is near the midpoint along the edge of the antenna and not at the vertices. A four element diversity antenna is designed that has dual band (2.45;5.25, 5.8 GHz) and dual linear polarization capabilities.

**Index Terms**-- Microstrip antenna, diversity antenna, mutual coupling

## I. INTRODUCTION

There is a growing body of literature on the implementation of diversity reception for personal devices (mobile stations) in cellular communications. The use of a space diversity antenna at the mobile station necessitates reduced element spacing, which can lead to increased mutual coupling. The disadvantages of a large mutual coupling are the reduction in the antenna element radiation efficiency, the decrease in the antenna element effective gain, and the reduction in the average received power of the diversity antenna [1-3]. Our previous work demonstrated the reduction of mutual coupling using orthogonal polarization for adjacent antenna elements [4]. Additionally, polarization diversity can be as effective as space diversity, but with a more physically compact antenna structure [5].

Diversity reception techniques are beginning to be expanded to Wireless Local Area Networks (WLAN) [6], wherein the highly scattering indoor and outdoor picocell environments have been shown to be particularly advantageous for polarization diversity techniques [7,8].

The use of a small number of elements in the diversity antenna is preferred because the greatest degree in improvement in the diversity gain occurs in going from a single branch system to a two or four branch system (two branches give 11.5 dB gain at the 99 % reliability level and four branches give 19 dB gain for maximal ratio combining) [9].

In this paper we present an analysis of proximity coupled microstrip antenna elements arranged to form a dual band, dual linear polarization antenna system. The antenna system is designed for the WLAN 802.11a (5.25, 5.8 GHz) and 802.11b (2.45 GHz) communications standards with each frequency band having an independent feed port. The motivation is to identify array topologies that minimize the mutual coupling under the constraint of small interelement spacing. This work only considers single polarized antenna elements for clarity and conciseness. The use of dual polarized antenna elements may be a topic of future research.

## II. MPIE MOM FORMULATION

The analysis and design of the antennas in this research was accomplished using a mixed potential integral equation method of moments software [10]. A brief description of the theoretical analysis germane to the calculation of the scattering parameters is included for completeness.

The geometry of a proximity coupled microstrip antenna is shown in Figure (1). The electric current  $\mathbf{J}_1$  on the lower microstrip line and the electric current  $\mathbf{J}_2$  on the upper microstrip antenna are modeled with the triangular patch sub-domain basis function,  $\mathbf{f}_n = \mathbf{tri}_n(\mathbf{r})$ . The total unknown electric current distributions are expressed as,

$$\mathbf{J}_1 = \sum_{n=1}^{M1} A_n \mathbf{f}_{n1}, \quad \mathbf{J}_2 = \sum_{n=1}^{N2} B_n \mathbf{f}_{n2} \quad (1)$$

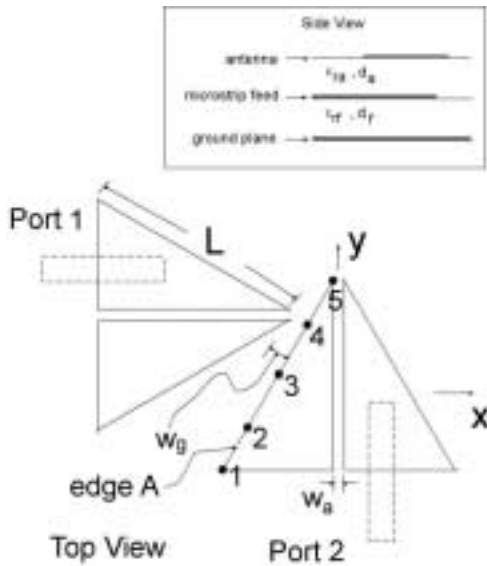


Figure 1. Geometry of two proximity coupled equiangular patch antennas orientated in perpendicular directions. Port 1 radiates an x-directed field. Port 2 radiates a y-directed field.  $\epsilon_{ra} = \epsilon_{rf} = 2.2$ ,  $d_a = d_f = 1.57$  mm.

The use of Galerkin's procedure transforms the system of coupled integral equations to a system of linear equations  $[\mathbf{V}] = [\mathbf{Z}][\mathbf{I}]$ . In this analysis, the excitation mechanism is an impressed electric field  $\mathbf{E}_{inc}$  generated by a series unit voltage gap source placed across the positive to negative triangles of a single basis function near the end of the microstrip feed line.

In order to extract the S parameters for the 2-port network, transmission line theory is applied. Away from the antenna and feed point, the microstrip feed line supports only the quasi-TEM mode. The current at a cross section in the dominant mode region is expressed as an incident and reflected wave with unknown coefficients  $A_i$ ,  $B_i$ . From the solved coefficients  $[\mathbf{I}]$  the current is sampled at 5-10 locations and the coefficients  $A_i$  and  $B_i$  are extracted then averaged. The scattering parameters are then determined

### III. ANTENNA GEOMETRY AND MUTUAL COUPLING ANALYSIS WITH DISCUSSION

The geometry of two proximity coupled equiangular triangle patch antennas is shown in Figure 1. The  $50 \Omega$  microstrip feed is embedded within the antenna substrate and the ground plane. The advantages of this design are the noncontact vertical transition and

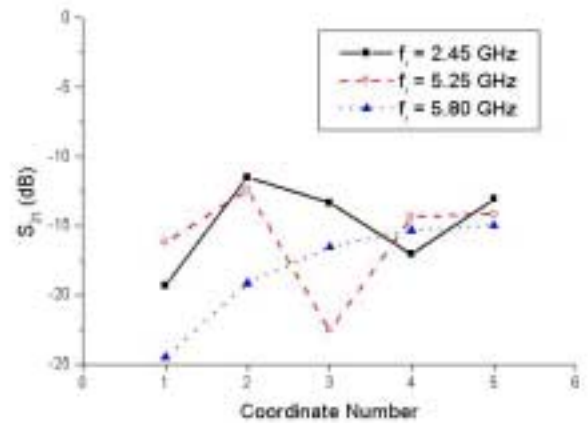


Figure 2. Theoretical mutual coupling (between same band antenna elements) for different placements along edge A for three frequencies.

the potential use of different substrate materials. The impedance matching of the antenna is accomplished by offsetting the feedline open end underneath the antenna.

The original antenna geometry is a single equiangular triangle. The impedance bandwidth for the lower frequency band,  $f_1 = 2.45$  GHz, is not attainable with the original geometry. This is due to the electrically thin substrate. The impedance bandwidth for the upper frequency band,  $f_2 = 5.25$  GHz and  $f_3 = 5.8$  GHz, is also not attainable (within a single bandwidth) with the original geometry due to the same reason.

One technique to obtain a broader bandwidth is to take advantage of the resonant current distribution flowing on the antenna. For example, the lowest order mode,  $TM_{01}$ , for Port 2 in Figure 1 flows in the y-direction. By replacing the original equiangular triangle by two half-equilateral triangles, the impedance bandwidth can be increased by appropriately choosing the gap,  $w_a$ , between the two resonators. This technique, called gap coupling or multi-resonator antennas is well established and demonstrated previously for coax fed circular and triangular patch antennas [11]. We have extended this technique to create dual band behavior by using different dimensions for each resonator [12].

Using the above techniques, two antennas were designed. One was designed for a single band centered at 2.45 GHz, and the second one was designed for dual band centered at 5.25 and 5.8 GHz. The dimensions for the single band antenna are  $L_1 = 51.5$  mm,  $L_2 = 50.5$  mm, and  $w_a = 2.0$  mm. The dimensions for the dual band antenna are  $L_1 = 22.5$  mm,  $L_2 = 20.5$  mm, and  $w_a = 0.25$  mm. For brevity,

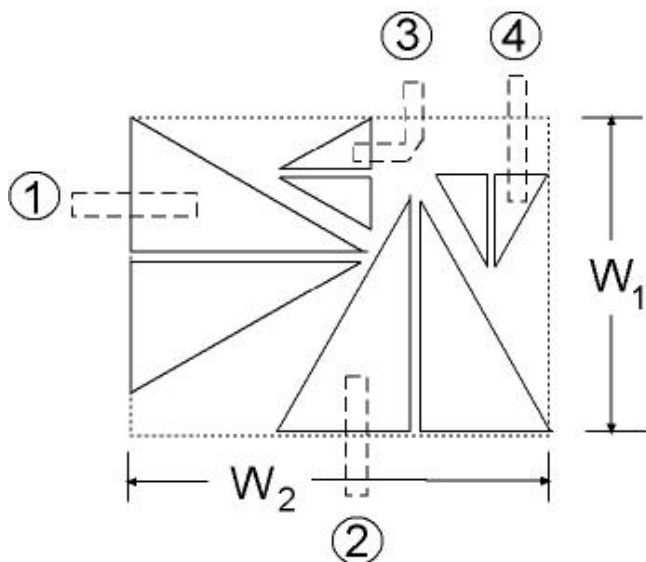


Figure 3. Theoretical dual mode antenna topology for minimum area and optimized mutual coupling.  $W_1 = 60$  mm,  $W_2 = 80$  mm.

the design process and frequency characteristics for the individual (isolated) antennas for each band are not included.

Since the antenna elements will be placed in close proximity to each other, an analysis of the mutual coupling between them (same band) is conducted to determine the optimum placement. The geometry of two elements is shown in Figure 1. The spacing is  $w_g = 1.0$  mm. The elements are orientated in perpendicular directions. Port 1 radiates a linear polarized field in the x-direction while Port 2 radiates a linear polarized field in the y-direction. The mutual coupling for different placements along edge A is shown in Figure 2.

The first case is for the single band antenna centered at 2.45 GHz. Since this is the physically larger element, determining the optimal placement along the edge is critical to reduce the total surface area occupied by two elements. We observe that the least mutual coupling (-19 dB) occurs at coordinate point 1. However, this will lead to the largest surface area. As the first element is moved along the edge the mutual coupling increases, at the same time reducing the total surface area. There is a local minimum at coordinate point 4 of -17 dB providing an optimum compromise between mutual coupling and surface area.

The second case is for the dual band antenna centered at 5.25 and 5.8 GHz. We observe that the mutual coupling response at 5.25 GHz displays a similar trend

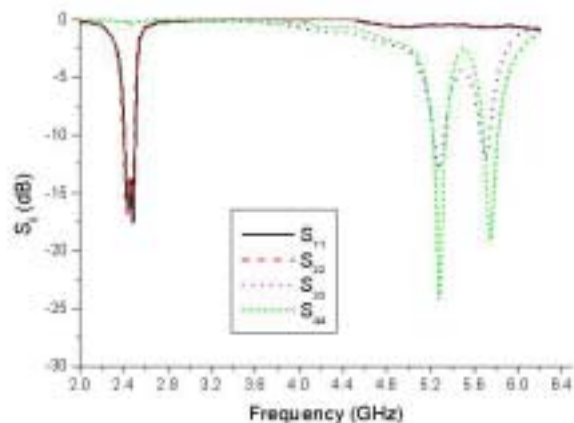


Fig. 4. Theoretical reflection coefficients for dual mode antenna.

to the first case. The optimal location is now centered along the edge

The response at 5.8 GHz is different, increasing gradually as the first element is moved along the edge. The reason may be the non-symmetric geometry of the element. In the analysis the edge A corresponds to the resonator at 5.25 GHz. The analysis will be repeated for edge A corresponding to the resonator at 5.8 GHz to compare the results.

#### IV. DUAL MODE DIVERSITY ANTENNA

The mutual coupling analysis for the single band antenna centered at 2.45 GHz is important for determining the optimum placement between the two elements with regards to reduced mutual coupling and minimum total area. It was determined the location of the first element should be at coordinate 4, or  $\frac{3}{4}$  distance from the base of the second element. With this finding, the dual band antenna elements centered at 5.25 and 5.8 GHz were placed in the unoccupied areas near the larger elements. The antenna topology for the four elements is shown in Figure 3. The side lengths of the rectangular area occupied by the four elements are  $W_1 = 60$  mm and  $W_2 = 80$  mm. The only modification to the isolated antenna geometry was the feedline offset to account for the mutual coupling between the elements.

The theoretical scattering parameters are shown in Figures 4 and 5. The impedance bandwidths are sufficient to cover the required frequency ranges. The frequency response of Port 3 at 5.8 GHz has been

slightly perturbed due to the possible interaction of its feedline with the antenna element of Port 4. The mutual coupling parameters are below  $-15$  dB within the impedance bandwidths. The greatest mutual coupling occurs between Port 1 and Port 2, since they are closer electrically. The mutual coupling between Port 3 and Port 4 is about  $-25$  dB.

## V. CONCLUSION

The use of diversity reception techniques is becoming increasingly important for wireless local area networks. The particular use of orthogonal polarization for the branches is particularly attractive for the highly scattering environment. This paper has presented an analysis of triangular microstrip antennas to determine the optimum placement to minimize the mutual coupling and reduce the total surface area. The optimum location was determined to be near the midpoint along the edge of the antenna and not at the vertices. From the results, a four element antenna was designed that had dual band and dual linear polarization. Each band had its own feed port. The design is compatible for dual mode 802.11a,b WLAN standards.

## REFERENCES

- [1]. R. G. Vaughan and J. Bach Andersen, "Antenna diversity in mobile communications," *IEEE Trans. Veh. Technol.*, Vol. VT-36, No. 4, pp. 149-172, Nov. 1987.
- [2]. T. Taga, "Characteristics of space-diversity branch using parallel dipole antennas in mobile radio communications," *Elect. Commun. in Japan, Part 1 (Commun.)*, Vol. 76, No. 9, pp. 55-65, September 1993.
- [3]. K. Ogawa and T. Uwano, "Analysis of a diversity antenna comprising a whip antenna and a planar inverted F-antenna for portable telephones," *Elect. Commun. in Japan, Part 1 (Commun.)*, Vol. 80, No. 8, pp. 39-49, August 1997.
- [4]. R. R. Ramirez and F. De Flaviis, "A mutual coupling study of linear polarized microstrip antennas for use in BLAST wireless communications architecture," *Proc. IEEE AP-S International Symposium* Vol. 2, pp. 490-493, Salt Lake City, UT, USA, July 2000.
- [5]. A. M. D. Turkmani, A. A. Arowojolu, P. A. Jefford, and C. J. Kellet, "An experimental evaluation of the performance of two-branch space and polarization diversity schemes at 1800 MHz," *IEEE Trans. Veh. Technol.*, Vol. 44, No. 2, pp. 318-326, May 1995.

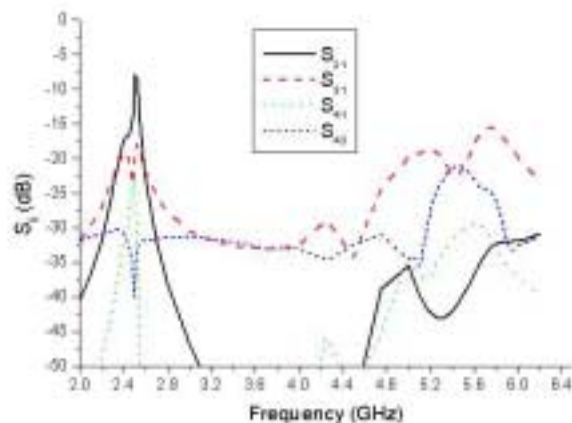


Fig. 5. Theoretical mutual coupling scattering parameters for dual mode antenna.

- [6]. A. Kamerman and L. Monteban, "Wavelan-II: A high-performance wireless LAN for the unlicensed band," *Bell Labs Technical J.*, Vol. 2, No. 2, pp. 118-133, Summer 1997.
- [7]. D. C. Cox, R. R. Murray, H. W. Arnold, A. W. Norris, and M. V. Wazowicz, "Cross-polarization coupling measured for 800 MHz radio transmission in and around houses and large buildings," *IEEE Trans. Antennas Propagat.*, Vol. AP-34, No. 1, pp. 83-87, Jan. 1986.
- [8] J.H. Reed, T. S. Rappaport, B. W. Woarner, Ed. *Wireless Personal Communications: advances in coverage and capacity*, Kluwer Academic Publishers, Boston, MA, 1997.
- [9]. W. C. Y. Lee, *Mobile Communications Engineering, Theory and Applications, Second Edition*, McGraw-Hill, New York, NY, 1998.
- [10]. M.-J. Tsai, F. De Flaviis, O. Fordham, and N. G. Alexopoulos, "Modeling planar arbitrarily shaped microstrip elements in multilayered MIC/MMIC media," *IEEE Trans. on Micro Theory Tech.*, Vol. 45, No. 3, pp. 330-337, March 1997.
- [11]. M. B. Nile, S. L. A. A. Rasheed, and G. Kumar, "Broadband gap coupled semicircular and triangular microstrip antennas," *Proc. IEEE AP-S International Symposium* Vol. 2, pp. 1202-1205, New York, NY, USA, July 1994.
- [12]. R. R. Ramirez, H. Elsadek, L. Jofre, and F. De Flaviis, "Reduced size single and dual band linear polarized microstrip antennas for mobile communications," *Proc. IEEE AP-S International Symposium*, Vol. 4, pp. 450-453, Boston, MA, USA, July 2001