Microstrip Array Antennas for Point-to-Point WLAN Links

Ghaith Mansour
Department of Electrical & Electronic Engineering, Sirte University
Sirte, Libya
g.mansour@su.edu.ly

Ekasit Nugoolcharoenlap
Department of Electrical Engineering, Rajamangala University of Technology Rattanakosin, Thailand
ekasit.nug@rmutr.ac.th

Abstract—Microstrip array antennas for point-to-point WLAN links are presented. Three designs are proposed including 2x1 patch array, 4x1 patch array, and 4x2 patch array. The radiating patches are of rectangular shape and fed using the inset feed method. The realized gains for the arrays are 7.9, 11.7, and 14.3 dB respectively. The proposed antennas provide a good return loss, directional radiation patterns, and high gains. The 2x1 patch array was fabricated and measured. The proposed antennas are simulated using the 3-D electromagnetic solver of CST®.

Index Terms: microstrip antenna, array antenna, Wi-Fi, WLAN, point-to-point link, wireless communications.

I. INTRODUCTION

802.11 WLAN technology is widely used to provide wireless access networks with a maximum range of 100 m. The range of the Wi-Fi network can be extended to several kilo meters by using highly directive antennas. This implementation is known as point-to-point link. It provides a good alternative for using cables over long distances to connect network segments. Wi-Fi based point-to-point links can increase the range of WLAN, provide network scalability, and other advantages such as high gain and high throughput [1].

In high-performance applications where performance, size, and weight are constraints, low-profile antennas are preferred [2]. Microstrip antennas are low-profile, conformable to planar and non planar surfaces [3], simple and inexpensive to fabricate. Furthermore, by adding loads between the patch and the ground plane, such as pins and varactor diodes, adaptive elements with variable resonant frequency, impedance, polarization, and pattern can be designed [4], [5], [6]. Reconfigurable Microstrip antennas for cognitive and software-defined radios have been presented in [7-9].

Microstrip antennas suffer from several disadvantages such as narrow bandwidth and low efficiency. However, there are techniques, such as increasing the thickness of the substrate which can be used to increase the bandwidth and the efficiency. Microstrip antennas also suffer from low directivity, which can be improved by using array antennas. Microstrip arrays are versatile and used to synthesize a desirable that can't be obtained from a single patch [10-14].

Microstrip array antennas for point-to-point Wi-Fi links are proposed. An inset-fed rectangular patch is initially designed to operate in the 2.4 GHz WLAN band. Then, the patch is expanded into 2x1 array using a T-junction power divider. The power divider is a T junction of three transmission (microstrip) lines. Quarter wavelength transformers are used to provide impedance matching. In order to increase the directivity, 4x1 and 4x2 microstrip arrays are also proposed. The proposed antennas are designed using the transmission line model and simulated using the 3-D solver of CST®. The 2x1 patch array has been fabricated and measured. A good agreement is found between the simulated and measured results.

II. ANTENNA DESIGN

The proposed microstrip antenna is shown in Figure 1. It consists of a rectangular patch fed by a microstrip line. The patch is printed on FR4 dielectric substrate with thickness (h) of 1.6mm and dielectric constant εr =4.5. The length of the patch (L) is approximately half wavelength at the operating frequency of 2.4 GHz as given by:

\[ L = \frac{\lambda}{2} = \frac{C}{2f_0 \sqrt{\varepsilon_r}} \]  

where \( C=3x10^8 \) is the speed of light, \( f_0 \approx 2.4 \) GHz is the resonant frequency, and \( \lambda \) is the guided wavelength. The length \( L \) is calculated using (1) and found to be \( L = 28.5 \) mm.

The width of the patch doesn't affect the resonant frequency. However, it affects the input impedance and the radiation efficiency. The width (W) is chosen to obtain the highest possible radiation efficiency. The width is given by:

\[ W = \frac{C}{2f_0} \sqrt{\frac{2}{\varepsilon_r + 1}} \]  

The width is thus calculated and found to be \( W = 38 \) mm.
The matching technique is the inset fed. It is based on moving the feeding point towards the centre of the patch to obtain a good impedance matching. This is achieved by creating a slot in the patch and moving the feed line through it. The design equations for the inset feed are presented in [2]. However, in this project the dimensions are obtained from EM simulations and found to be \( X_0 = 2 \) mm and \( Y_0 = 9 \) mm.

The proposed 2x1 microstrip array is shown in Figure 2. The array antenna consists of two patches connected using a T-junction power divider. The power divider divides the input power equally (both phase and magnitude) between the radiating patches [15]. The input line of the power divider has an impedance of 50\( \Omega \). In order to provide a good impedance matching, the output lines have impedances of 100\( \Omega \). Thus, when combined in parallel, their equivalent resistance is 50\( \Omega \) resulting in a matched condition. Quarter wavelength transformers are used to match the 100\( \Omega \) output lines to the patches.

The impedance of the quarter wavelength transformer is given by

\[
Z_T = \sqrt{Z_1Z_2} = \sqrt{50 \times 100} = 71\Omega
\]  

where \( Z_T \) is the impedance of the transformer, \( Z_1 \), and \( Z_2 \) are the impedances of the two transmission lines to be matched. The 2x1 array has been fabricated as shown in Figure 2b.

The proposed 4x1 patch array antenna is shown in Figure 3. The antenna consists of three T-junction power dividers and four patches. The power dividers split the input power equally between the four radiating patches. The antenna is fed using a coaxial connector. The feeding pin is soldered to two parallel 100\( \Omega \) lines. Thus, there is no impedance mismatch at the feeding point. 3/4 transformers are then used to bring the impedances back to the 50\( \Omega \) level as in the 2x1 array.

The 4x2 patch array is shown in Figure 4. The array consists of 8 elements and is expected to provide higher gain and directivity than the lower order arrays. This array is a combination of 4x2 power dividers and eight radiating patches.
III. SIMULATION AND MEASUREMENT RESULTS

The simulated reflection coefficients of the proposed prototypes are shown in Figure 5. The proposed antennas exhibit good impedance matching with $S_{11}$ being below -10 dB within the operating bandwidth. A good agreement between simulated and measured reflection coefficients is obtained for the 2x1 array as shown in Figure 6. A small shift in the resonance frequency is observed in the measured result. The simulated and measured resonance frequencies are 2.44GHz and 2.54GHz respectively. The discrepancy is due to variation in the dielectric constant which has a tolerance of ±0.3.

The simulated radiation patterns for the proposed arrays are shown in Figure 7. The realized gains for the 2x1 array, 4x1 array, and 4x2 array are 7.9, 11.7, and 14.3 dB respectively. The half-power beamwidth in the E plane are 100°, 32°, and 30° respectively. The half-power beamwidth in the H plane are 40.7°, 38.1°, and 18.9° respectively. Thus, the gain increases with the order of the array as expected. All proposed arrays provide good and directional patterns with maximum power normal to the centre of the ground plane. The cross polarization level is very low and thus can't be observed in the polar plot of the radiation patterns.
The 3-D radiation patterns for the 4x1 and 4x2 arrays are shown in Figure 8. A few side lobes are observed in the pattern. These side lobes can be minimized by optimizing the spacing between the radiating patches. The radiation pattern parameters are summarized in Table 1.

IV. CONCLUSION

Microstrip array antennas for long-range WI-Fi links have been proposed. A single patch, 2x1 patch array, 4x1 patch array, and 4x2 patch array are presented and discussed in details. The proposed prototypes provide good impedance matching, good radiation patterns and good gains. The directivity and the gain increase with the order of the array. The 4x2 array has the highest gain of 14.33 dB and the highest directivity with HPBW of 18.9° and 30° in the H and E planes respectively. Thus, it has the ability to concentrate the power in a single direction as required for point-to-point links.
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REFERENCES


