

# Design of Novel Hexagonal Shape Microstrip Patch Array for Bluetooth, WLAN and WiMAX Applications

Chaw Myat Nwe  
Department of Electronic Engineering  
Mandalay Technological University  
Mandalay, Myanmar

Khaing Wai Pyone  
Department of Electronic Engineering  
Technological University (Loikaw)  
Loikaw, Myanmar

**Abstract**— Today dual or multiband antenna has been playing a vital role for wireless service requirements. This paper presents a 1×2 hexagonal shaped patch array for Bluetooth, WLAN and WiMAX applications. Array antennas are used to enhance performance especially in gain of the antenna. The presented antenna is designed a size of 50×50×1.6mm<sup>3</sup> on a FR4 substrate and covers the frequency range from 2.4 to 5 GHz, with bandwidth 2.6GHz and 5.5 to 6.36GHz, with bandwidth 860MHz. The maximum directivity gain achieved here is 4dBi. The micro strip feed line is defected in order to enhance the return loss and cover the desired frequency range of antennas. The antenna has input impedance of 50 ohms to achieve the maximum power transfer and ensuring minimum reflection losses.

**Keywords**— Microstrip Patch Array Antenna; Gain; Bandwidth; Feed Techniques; Dielectric.

## I. INTRODUCTION

As current and future technology trends in wireless communication have increased, the demand for patch antennas that can work at various bands with sufficient bandwidth will more needed. Design requirements have encouraged that antenna researchers need to design a multiband antenna with the purpose to improve the wireless quality and increase the application areas. Besides these, multiband antennas also fulfill their success in the field of cost, size and high data rate features. In this research work, a 1×2 hexagonal shape patch array antenna with micro strip line feed is designed for applications such as Bluetooth operating at 2.4GHz and WLAN frequency bands at 3.3GHz, 3.5GHz and WiMAX .

Microstrip antenna suffers from bandwidth limitations. The bandwidth can be increased by adding loss elements but it affects efficiency of the antenna. So the better method is to use array antenna. Micro strip antennas are used in arrays as well as single elements [2].

By using array in communication systems we enhance the performance of the antenna like increasing gain, directivity scanning the beam of an antenna system, and other functions which are difficult to do with the single element. This antenna is simulated using FEKO software. The simulated performances of the antenna such as gain, S-parameter and radiation pattern are measured.

## II. ANTENNA DESIGN

### A. Substrate consideration

Micro strip patch antennas consist of very thin metallic strip placed on ground plane where the thickness of the metallic strip is restricted by  $t \ll \lambda_0$  and the height is restricted by  $0.0003\lambda_0 \leq h \leq 0.05\lambda_0$ . There are numerous substrates that can be used for the design of micro strip antennas and their dielectric constants are usually in the range of  $2.2 \leq \epsilon_r \leq 12$  [1] [2]. According to the restricted and easily find in Myanmar market, 1.6mm thick FR4-epoxy substrate, with a permittivity of 4.4 and loss tangent 0.018 are chosen to obtain optimal design.

### B. Patch Width

The patch width depends on the two parameters like center frequency and dielectric constant of materials.

$$W = \frac{c}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} \quad (1)$$

Where, W = Width of Substrate Material

$f_0$  = Centre Frequency

$\epsilon_r$  = Relative Permittivity or Dielectric Constant.

### C. Effective Dielectric Constant

Effective dielectric constant  $\epsilon_{eff}$  is introduced to account for fringing and the wave propagation in the line.  $\epsilon_{eff}$  can be found by the following mathematical relationship.

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[ 1 + \frac{12h}{w} \right]^{-0.5} \quad (2)$$

Where,  $\epsilon_{eff}$  = Effective Dielectric Constant

h = Height of Substrate Materials.

### D. Effective length

After the value of  $\epsilon_{eff}$  is calculated, the effective length of the patch  $L_{eff}$  now becomes:

$$L_{eff} = 0.5 \frac{\lambda}{\sqrt{\epsilon_r}} \quad (3)$$

**E. Length Extension**

To calculate effective length extension at each side along the patch,  $\Delta L$  by the equation:

$$\Delta L = 0.412 \left( \frac{\epsilon_{re} + 0.3}{\epsilon_{re} - 0.3} \right) \left[ \frac{\left[ \frac{w}{t} + 0.264 \right] h}{\left[ \frac{w}{t} + 0.8 \right]} \right] \quad (4)$$

**F. Patch Length**

The dimensions the patch along its length have now been extended on each end by a distance  $\Delta L$ , the patch length (L) equation now becomes

$$L = L_{eff} - 2\Delta L \quad (5)$$

**G. Other parameters for circular patch**

Other parameters for designing the hexagonal shape are reactance of circular patch and resonance frequency. Primarily, circular patch is designed to be resonated at the fundamental resonance frequency which is approximately given by:  $X_{mn} = 1.8411$ ,  $f_r = 3.3\text{GHz}$ . The effective radius of the circular could be calculated based on the height, dielectric constant.

$$f_r = \frac{X_{mn}}{2\pi a_e \sqrt{\epsilon_r}} c \quad (6)$$

- Where,  $X_{mn}$  = Reactance of Circular Monopole Antenna
- $a_e$  = Effective radius of the circular patch
- $c$  = Velocity of light in free space.

The effective radius of the circular could be calculated based on the height, dielectric constant.

$$a_e = a \left[ 1 - \frac{2h}{\pi a \epsilon_r} \left( \ln \frac{\pi}{2h} + 1.7726 \right) \right] \frac{1}{2} \quad (7)$$

In the above expression, 'a' is the actual radius of the circular patch antenna.

The side length of hexagonal patch antenna is

$$\pi a_e^2 = \frac{3\sqrt{3}}{2} s^2 \quad (8)$$

Ground plane of substrate can be calculated the following.

$$L_g = L + 6h \quad (9)$$

$$w_g = w + 6h \quad (10)$$

Micro strip feed line of array is

$$L = \frac{\lambda}{4} = \frac{\lambda_0}{4\sqrt{\epsilon_{reff}}} \quad (11)$$

and feed line width  $W_0$

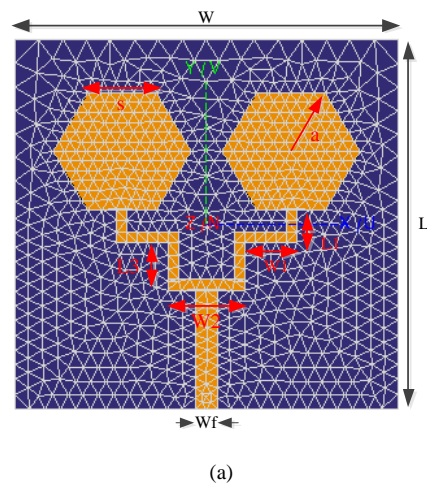
$$z = \frac{120\pi}{\sqrt{\epsilon_r \left[ \frac{h}{w} + 1.393 + 0.667 \ln \left( \frac{h}{w} + 1.444 \right) \right]}} \quad (12)$$

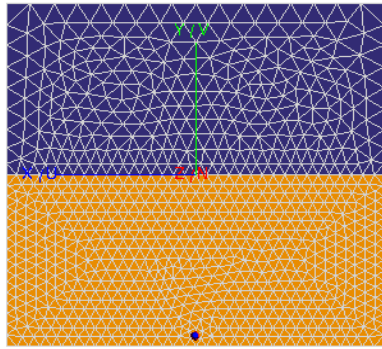
By using above equations, hexagonal shape micro strip patch array dimensions are shown in Table 1. All of these parameters were selected to achieve compact 1x2 hexagonal shape antenna design. Here two patch elements are used and each element has same dimensions as mentioned above in order to increase antenna performance.

TABLE I. THE DIMENSIONS OF THE DESIGNED ANTENNA

Design Parameters	Length in (mm)	Design Parameters	Length in (mm)
$W_g, L_g$	50, 24	a	7.5
$W, L$	50, 50	s	10
$W_f$	3	h	1.6
$W_1, W_2$	8.2, 10	$E_r$	4.4
$L_1, L_2, L_3$	3, 1.4, 5	Feed point	0.35

Fig.1 shows the general configuration of proposed hexagonal shaped patch array. Where 1x2 diamond shaped patch array is placed over the substrate having dielectric constant of 4.4 and the thickness of substrate is 1.6mm and ground plane is printed on other side of the patch.





(b)  
 Fig.1 Design of 1x2 Hexagonal Patch Array Antennas  
 (a) Front view (b) Bottom view

### III. RESULT

#### A. S-parameter plot for return loss versus frequency

Return loss is an important parameter when testing an antenna. It is related to impedance matching and the maximum transfer of power theory. It is also a measure of the effectiveness of an antenna to deliver of power from source to antenna. S-calculation has been performed for hexagonal micro strip 1x2 array antennas. Fig.2 shows the antenna operates at a dual frequency band of 2.4 to 5 GHz, with bandwidth 2.6GHz and 5.5 to 6.36GHz, with bandwidth 860MHz. The simulated results shows the maximum return loss at -32dB and -50dB which can cover Bluetooth, WiMax and WLAN application.

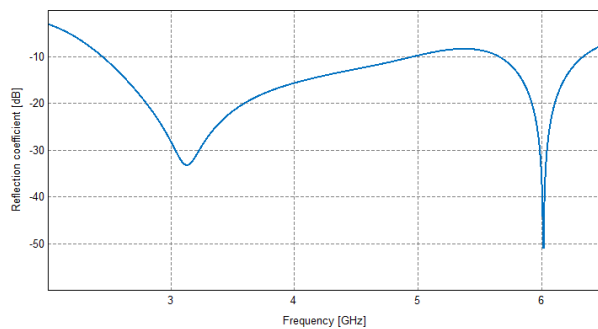


Fig. 2 Return Loss of 1x2 Array Patched Antenna

#### B. Radiation Pattern

The simulated radiation patterns of the designed antenna are plotted using CADFEKO EM-simulation software and validated results are given in Fig. 3 through 5 at three different resonating frequencies of (2.4GHz, 3.35GHz and 5.54GHz). The designed antenna shows radiation pattern nearly omnidirectional in H-plane and bi-directional in E-plane, provided that antenna has good radiating properties at their operating bands.

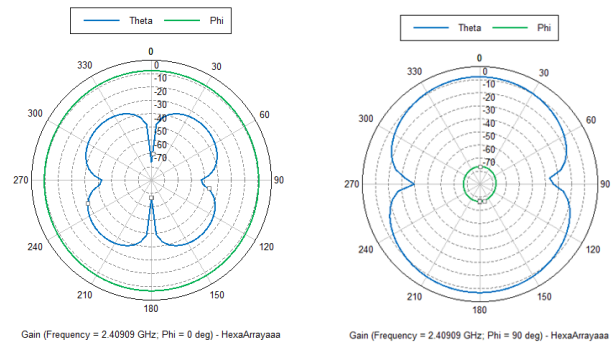


Fig. 3 XZ-Plane and YZ-Plane for Bluetooth

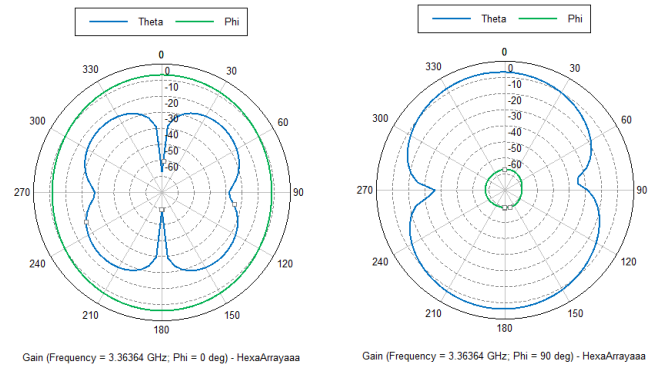


Fig. 4 XZ-Plane and YZ-Plane for WiMAX

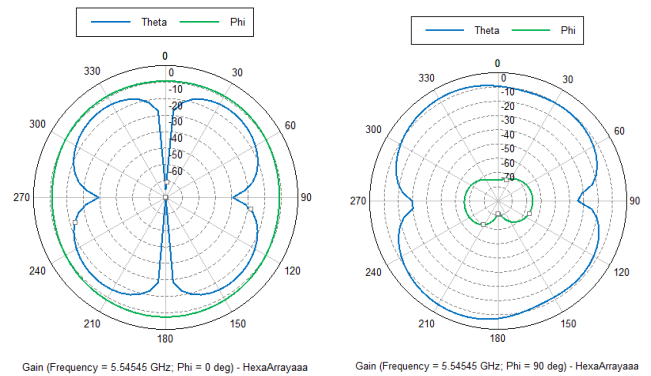


Fig. 5 XZ-Plane and YZ-Plane for WLAN

#### C. 3D Directivity Gain

3D radiation of the antenna can be found from the Fig.6. According to the radiation pattern, the type of the antennas can be said all antennas are the bidirectional antenna. The 2x1 array types of patch can provide directivity in the range 4-4dBi.

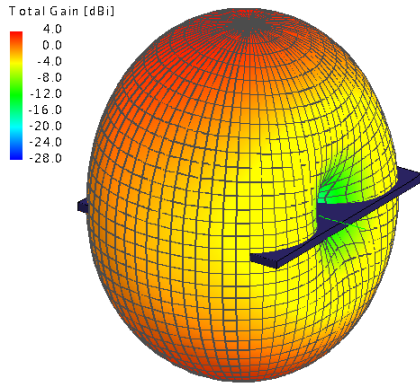


Fig. 6 3D Radiation Pattern

#### IV. CONCLUSIONS

In this paper, the two hexagonal shape microstrip patch array has been designed for Bluetooth, WiMAX and WLAN applications. A compact 1x2 array antenna is used to control surface current distribution on the patch antenna to achieve triple-band operation. Good radiation patterns and return loss characteristics, higher gain and low cross-polarization levels was achieved. This triple band antenna is suitable to cover the IEEE 802.11 Bluetooth, WLAN standards of 2.4GHz, 5.15-5.35GHz and WiMAX band of 3.35GHz.

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#### D. Surface Current Distribution

The surface current distribution is shown in Fig. 7. It can be seen that there is a significant concentration of the current in the rounded parts of the patch and of the ground plane.

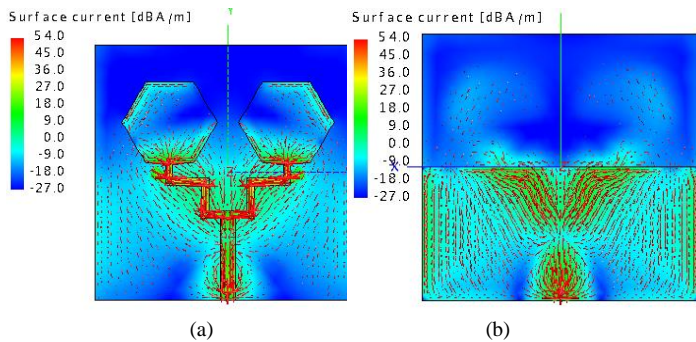


Fig 7 Current distribution of 2x1 array patched micro strip antenna  
(a) top view (b) bottom view