Microstrip Patch Antenna Array Design for WLAN and WIMAX Applications

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Abstract **– Microstrip antennas are currently one of the rapid growing antennas in modern telecommunication industry. Research has been carried out in the recent past to improve the efficiency and performance of these patch antennas.**

The objective of this paper is to design and fabricate a 16 element rectangular microstrip patch array antenna in S-band frequency range.

The simulation has been performed utilizing ADS software and the proposed antenna provided a return loss of -21.7 dB at 2.45 GHz and -19.6 dB at 2.54GHz. However, the gain of the antenna is found to be 13dBi. Since the resonant frequency of this antenna ranges from 2.378 to 2.594GHz, which is suitable for S-band applications such as WLAN (802.11b) and WiMAX in Libya.

Index Terms- **Microstrip antennas, Patch Antenna, WiMAX Antenna, WLAN Antenna, Wideband Antenna.**

I. INTRODUCTION

The concept of microstrip antenna was first introduced in 1953 by Deschamps. However, practical antennas were developed by Munson and Howell in the 1970s. The various advantages of microstrip antenna, such as its lightweight, small size, and ease of fabrication using printed-circuit techniques, have led to the design of several configurations for different applications. The microstrip antenna has been brought to the forefront because of the increasing requirements for personal and mobile communications, such as the demand for smaller and low-profile antennas.[1]

Microstrip patch antennas consist of metal patches large with respect to normal transmission-line widths. A patch radiates from fringing fields around its edges.

Impedance match occurs when a patch resonates as a resonant cavity. When matched, the antenna accomplishes peak efficiency. A normal transmission line radiates little power because the fringing fields are matched by nearby counteracting fields. [2]

Microstrip antenna has several advantages such lightweight, simple to manufacture and low profile. On the other hand it also has several disadvantages like low gain and narrow bandwidth with associated efficiency, these disadvantages can however be overcome with proper designs incorporated in whole antenna structures. One way to control these drawbacks is by introducing multiple patch antennas in array configuration.[3]

Advanced Design System (ADS) is used as the simulation software. ADS is an electronic design automation software system produced by AGILENT EEs. It provides an integrated design environment to designers of RF electronic products such as mobile phones, pagers, wireless networks, satellite communications, radar systems, and high speed data links.

II. DESIGN AND CALCULATIONS

The design of the array starts with a design of a conventional array operates in WIMAX and WLAN frequency range (2.4~2.6GHz), using FR4 ($\varepsilon_r = 4.4$) and thickness (h) of 1.6 mm, with input impedance of 50 Ω. A rectangular patch is used as geometry with inset fed, as shown in figure 1. The purpose of inset fed is to improve the impedance matching between the feed line and the element.

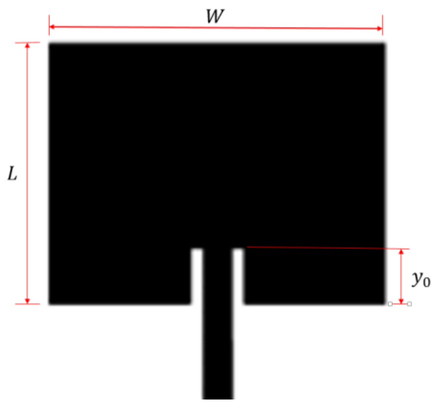

Figure 1. Single element rectangular patch antenna

The equations below are used to compute the length (L), width (W) and feed position (y_0) of patch antenna. [4]

1- Calculate ϵ_{reff} using the following common equation:

$$\epsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \times \frac{1}{\sqrt{1+12\frac{h}{W}}} \quad \ldots\ldots(1)$$

2- ΔL is the normalized extension of the length and given as

$$\Delta L = h \times 0.412 \frac{(\epsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \quad \text{………………(2)}$$

3- Calculate the value of L:

$$L = \frac{v_0}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L \quad \text{……………………………………(3)}$$

Where: f_r is the resonant frequency.
v_0 is the speed of light in free space.

4- Calculate W as:

$$W = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad \text{………………………………………….(4)}$$

5- feed of position y_0:
The inset distance y_0 is selected such that Z_o is equivalent to the feed line impedance (50 Ω).

$$y_0 = \frac{L}{\pi}cos^{-1}\sqrt{\frac{Z_0}{R_{in}}} \quad \text{……………………………………(5)}$$

Where R_{in} is The resonance input resistance.

$$R_{in} = \frac{1}{2(G_1+G_{12})} \quad \text{…………………………………………...(6)}$$

Where:
G_1 is The Conductance of a single slot.
G_{12} is The Mutual Conductance.

$$G_1 = \frac{1}{120\pi^2}\int_0^{\pi}\left[\frac{\sin\left(\frac{k_0W}{2}\cos\theta\right)}{\cos\theta}\right]^2 sin^3\theta\, d\theta \quad \text{……....(7)}$$

Where:
k_0 is The phase constant.
θ is the is the angle measured off the z-axis for radiation pattern for an Antenna.

$$G_{12} = \frac{1}{120\pi^2}\int_0^{\pi}\left[\frac{\sin\left(\frac{k_0W}{2}\cos\theta\right)}{\cos\theta}\right]^2 * J_0(k_0L\sin\theta)\cdot sin^3\theta\, d\theta \quad \text{……..…………(8)}$$

Where: J_0 is the Bessel function of the first kind of order zero.

TABLE 1 SHOWS THE DIMENSIONS OF THE PROPOSED ANTENNA.

Parameters	Dimension
Width W	36.51 mm
Length L	28.24 mm
Position of feed y_0	6 mm

III. DESIGN CONSIDERATION OF 4 BY 4 ARRAY

In this paper antenna array is designed and simulated instead of a single element antenna.

The first step of the design is to connect just two elements. The Wilkinson Power Divider is utilized as a method of connection. The value of impedance for elements and common port is (50Ω), Impedance matching is calculated by $Z_L = Z_o\sqrt{2} = 70\Omega$. The previous procedure can be used to design (2×2) and (2×4) feed network. After joining the two (2×4) networks, the feed of Coax is set in the middle between them. In this case, The Wilkinson Power Divider scheme is not used whereas two of 100Ω impedances are used for the connection. A coaxial feed is connected to the center of array from the other side of substrate. [5]

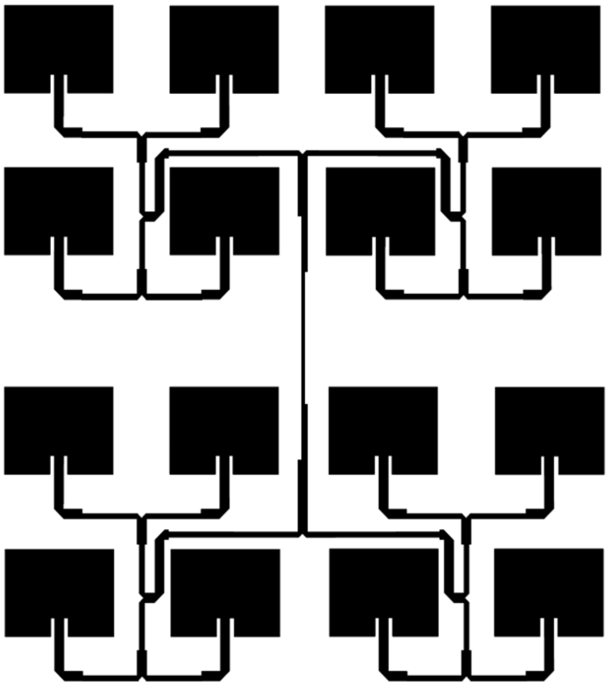

Figure 2. Four by four microstrip patch antenna array

IV. SIMULATION RESULTS AND DISCUSSION

The variation of the return loss versus the frequency of the antenna is shown in figure 3. Based on -10 dB return loss, it is clear that the bandwidth ranges from 2.378 GHz 'm3', to 2.594 GHz 'm4', This means that the value of bandwidth is 216MHz or 8.7%. This is larger than the bandwidth required, and adequate to guarantee that the scale is accomplished in the manufacturing process.

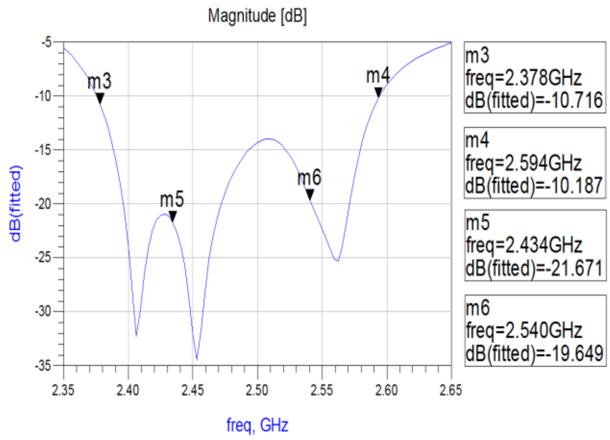

Figure 3. Return loss versus the frequency of the antenna.

Figure 4 illustrates the variation of the input impedance with frequency. It is obvious that the simulation results give the acceptable impedance matching at the resonant frequencies, where the impedance at 2.434 GHz is 44.15+j 5.15 Ω, and it is 41.1+j3.4Ω at 2.54 GHz.

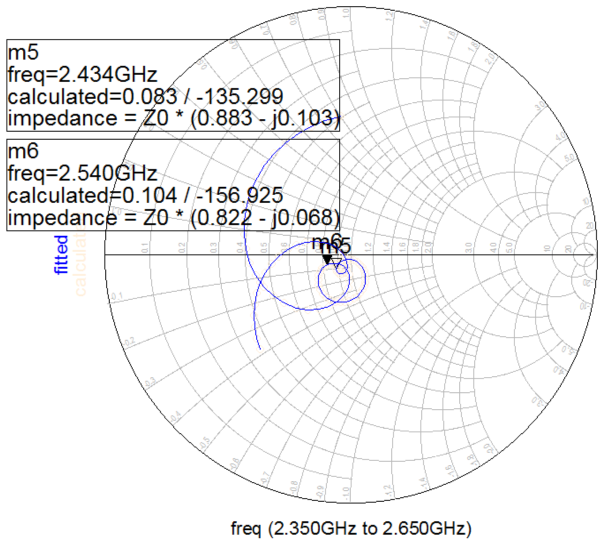

Figure 4. Variation of impedance versus frequency.

The simulation results of voltage standing wave ratio (VSWR) versus the frequency are illustrated in figure 5. The VSWR is 1.18 at 2.434 GHz for WLAN applications, and it is 1.233 at 2.54 GHz for WIMAX application. For VSWR less than 2, from figure 5, it can be observed that the slotted antenna covers the band from 2.375GHz to 2.597 GHz.

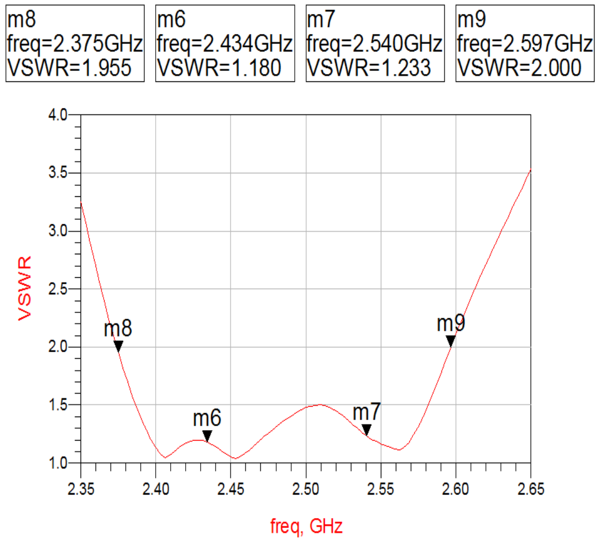

Figure 5. VSWR versus frequency for the proposed antenna.

Tables 2 and 3 shows the parameters of the designed antenna at 2.435 GHz and 2.54 GHz respectively.

TABLE 2 PARAMETERS OF THE ANTENNA AT 2.435 GHZ

Parameter	Value
Power radiation (mW)	1.45038
Effective angle (Steradians)	0.364332
Directivity (dBi)	15.3771
Gain (dBi)	13.0329
Maximum intensity (mWatts/steradian)	3.98094
Angle of U max (theta, phi)	12 271
E(theta) max(mag., phase)	1.73162 -53.4054
E(phi) max(mag., phase)	0.03123 126.056
E(x) max(mag., phase)	0.0016 116.579
E(y) max(mag., phase)	1.69407 126.594
E(z) max(mag., phase)	0.360024 126.595

TABLE 3 PARAMETERS OF THE ANTENNA AT 2.54 GHZ

Parameter	Value
Power radiation (mW)	1.17918
Effective angle (Steradians)	0.2978
Directivity (dBi)	16.2523
Gain (dBi)	13.0192
Maximum intensity (mWatts/steradian)	3.9591
Angle of U max (theta, phi)	17 272
E(theta) max(mag., phase)	1.72606 -151.107

E(phi) max(mag., phase)	0.0613081 29.828
E(x) max(mag., phase)	0.00379 44.1822
E(y) max(mag., phase)	1.65177 28.8945
E(z) max(mag., phase)	0.50465 28.8933

The 3D representation of the radiation pattern at 2.435GHz is shown in figure 6.

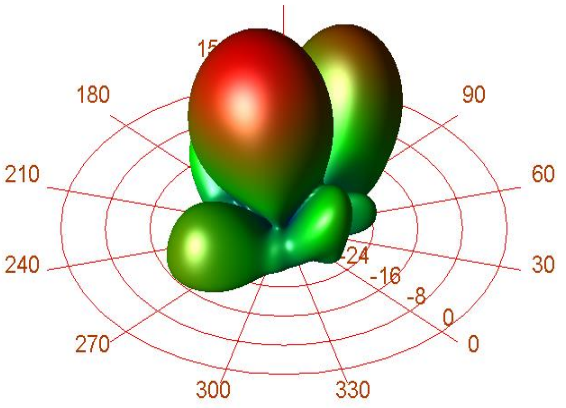

Figure 6. 3D radiation pattern of the antenna at 2.435 GHz

The 3D representation of the radiation pattern at 2.54GHz is shown in figure 7.

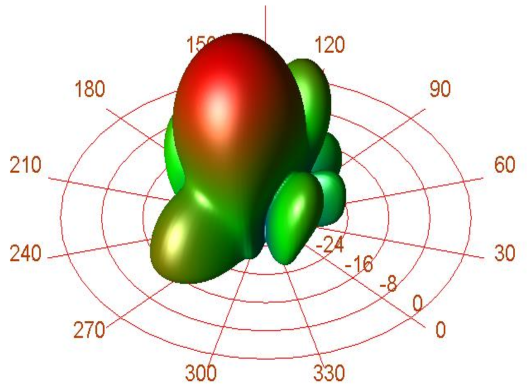

Figure 5. 3D radiation pattern of the antenna at 2.54 GHz

Field pattern at 2.435 GHz, of the (E_θ) and (H_ϕ) with θ=90 in elevation cut (x-y plane) is shown in figure 8.

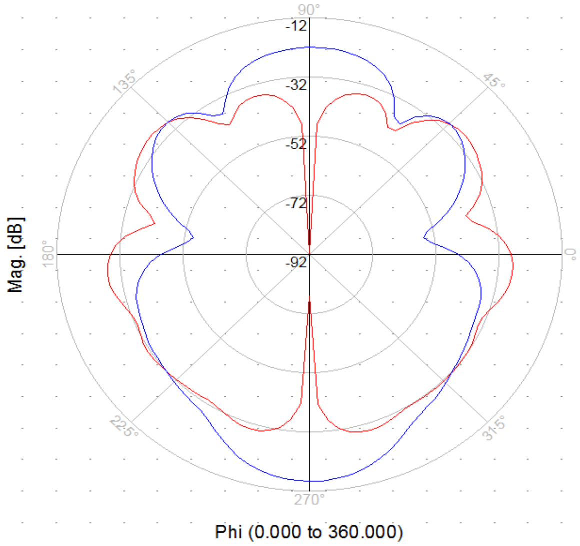

Figure 8. Field pattern at 2.435 GHz in x-y

Field pattern At 2.54 GHz, of the (E_θ) and (H_ϕ) with θ=90 in elevation cut (x-y plane), is shown in figure 9.

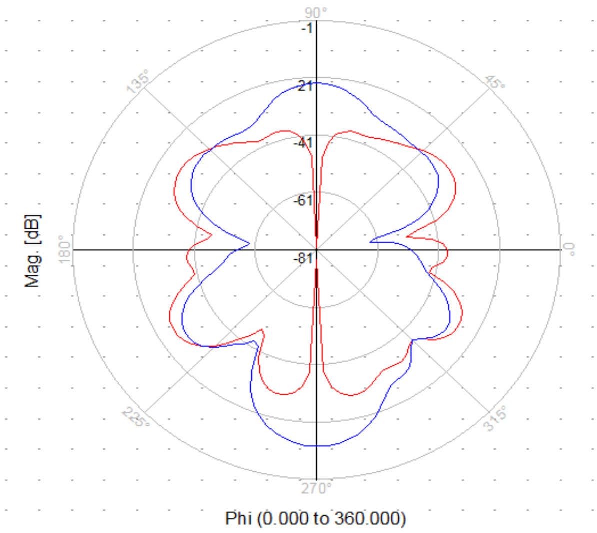

Figure 6. Field pattern at 2.54 GHz in x-y plane

Figure10 shows the Beamwidths of the antenna.it can be observed that the half power beamwidth (HPBW) is 30^o,and the first null beamwidth (FNBW) is 72^o at $\emptyset$=0°.

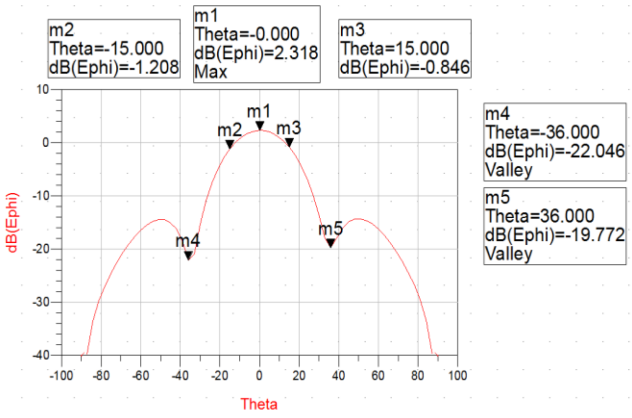

Figure 7. Beamwidths of the antenna at 2.435 GHz

Figure 11 shows the Beamwidths of the antenna.it can be observed that the half power beamwidth (HPBW) is 30^{o} ,and the first null beamwidth (FNBW) is 66^{o} at Ø=0°.

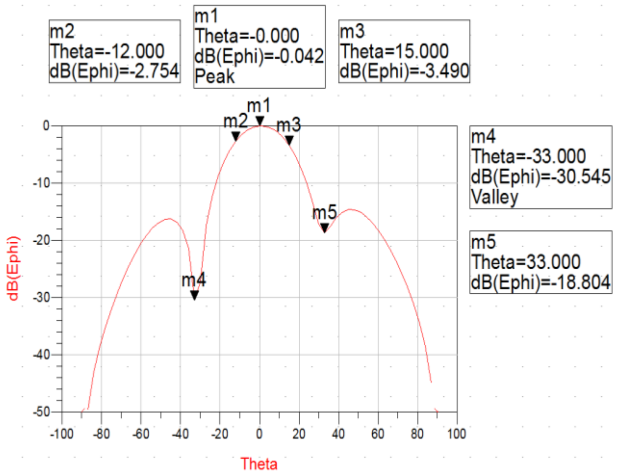

Figure 8. Beamwidths of the antenna at 2.54 GHz

The simulated current distributions at 2.435 GHz and at 2.540 GHz of the proposed antenna are presented in figure 12. Depending on the resonant frequency, it is obvious that, current distribution concentrates over the two paths of the currents.

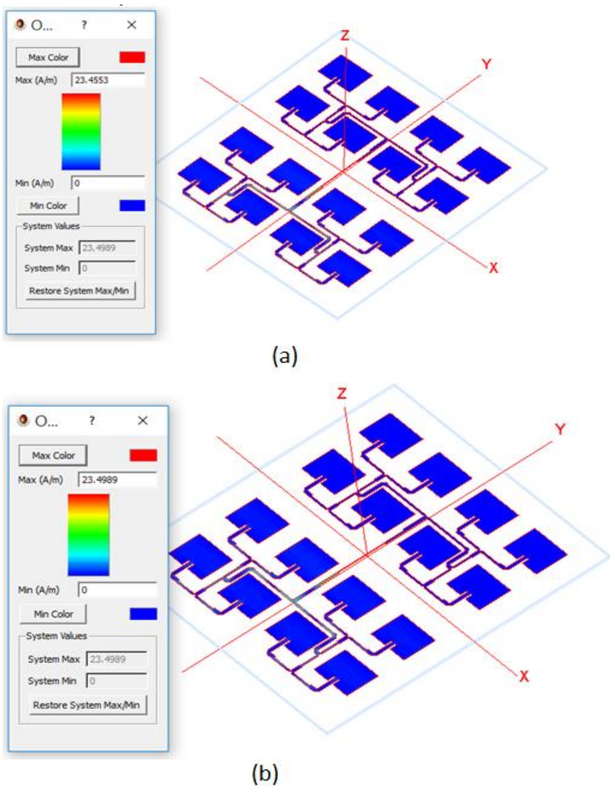

Figure 12. Current distribution at (a) 2.435 GHz (b) 2.540GHz

Figure 13 shows the fabricated patch antenna on a printed circuit board.

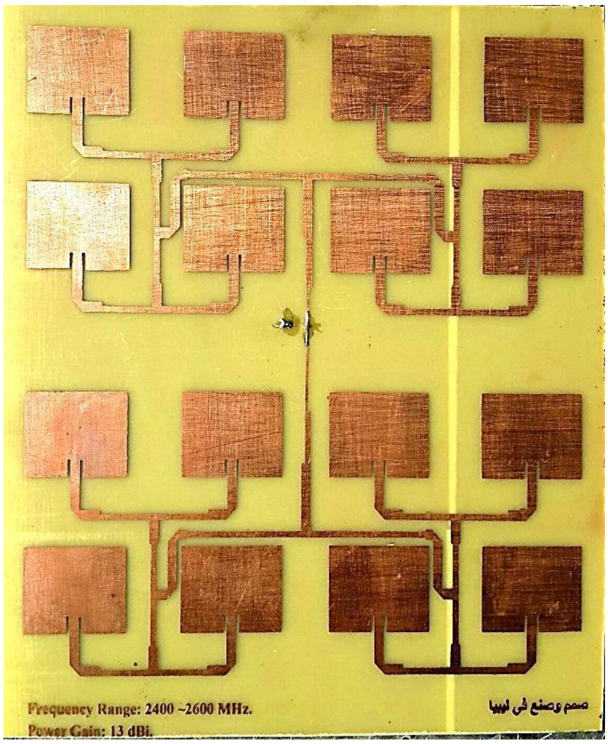

Figure 13. Fabricated Patch Antenna

A comparison between the proposed antenna and similar designs in terms of gain and bandwidth [6-7] is made in table 4.

TABLE 4 SHOWS THE PROPOSED ANTENNA WITH THE OTHER ANTENNAS

Design	Gain	Bandwidth (%)
Reference [6]	5dBi	6.1%
Reference [7]	10dBi	6.25%
Proposed antenna	13dBi	8.7%

V. CONCLUSION

In this paper, a Microstrip Patch Antenna Array Design for WLAN and WIMAX Applications was proposed and simulated using ADS Momentum software on FR-4 substrate with 4.4 dielectric constant and 1.6 mm thickness to operate at two wireless communication bands, WiMAX in Libya (2.505-2.575) GHz band, and WLAN IEEE 802.11b (2.4 – 2.48) GHz band. Sixteen elements of rectangles were designed to operate on 2.5GHz and linked together using Wilkinson Power Divider method with 50ohms-coaxial port cable.

The simulated results demonstrate that the antenna has a bandwidth of 216MHz or 8.7% and a gain of 13dBi for both WiMAX and WLAN. However, the directivity is 15.3dBi and 16.2dBi for WLAN and WiMAX respectively. Whereas, half power beamwidth is 30° for both bands.

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