International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 3 (2015) pp. 8221-8230

http://www.ripublication.com

Enhanced Gain And Reduced Size Circular Microstrip Patch Antenna Array For WiMAX Applications

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Abstract

This paper presents an enhanced and reduced size circular microstrip patch antenna array at 5.8 GHz. The antenna provides enhanced results compared to an existing antenna. The antenna is designed and simulated using Ansoft HFSS13.0 simulation software. The antenna dimensions are reduced by cutting the size of the ground plane as well as the dimensions of joints of the two patches. The simulation results presented are focused on the return loss, the gain, the VSWR and the bandwidth. The results show a significant improvement of 19% in the return losswith –38.11 dB, 10.55% in the antennagainwith 9.95 dB and 3% in the VSWR with 1.06. The antenna has achieved an impedance bandwidth of 160 MHz. The proposed antenna is reduced in size up to 21%. Hence, the proposed antenna results fulfil the specifications of WiMAX applications.

Keywords— Microstrip patch antennaarray, circular patch, gain enhancement, improved return loss, considerable bandwidth enhancement, directivity, directional radiationpattern, WiMAX.

I. INTRODUCTION

Antenna arrays provide a directional radiation pattern to meet the standards of WiMAX applications at 5.8 GHz. Despite of the remarkable growth in the telecommunication industry a low cost, high gain antenna with a directional radiation pattern without side lobes is a challenging task for researchers and antenna designers. Rectangular arrays are the most common type foundin antenna arrays.The Partical Swarm Optimization (PSO) algorithm approach in antenna design using a substrate with small dielectric constant helps in improving the return loss[1].

A stacked microstrip antenna with a truncated edge technique at its top and lower patch enhances return loss. The jointed configuration of two stacked patches has contributed to the significant reduction in antenna size compared to a conventional antenna that could yield the same antenna gain [2]. In recent years, some antenna design efforts focusing on directional antennas with high gain have been proposed [3-5].Antennas with rectangular arrays have also been reported in [6-8]. Circular patch antennas though are difficult to fabricate but provide a high gain and narrow beam width [9].A circular micro strippatch antenna with atwo-element array at 5.8 GHz using the corporate feeding technique is suitable for multi beam arrays. The antenna has a good circularly polarized radiation pattern with arelatively low return loss and high gain [10].

A circularly polarized microstrip patch antenna surrounded by a circular mushroom-like substrate for 5.8 GHz is reported in [11]. The antenna is fed by a coaxial probe. The proposed antenna is made of metallic rings. The simulated return loss of the single antenna is -15.6 dB and for the antenna array is -39.3 dB at 5.8 GHz while the gain is 4 dB.

A square patch microstrip antenna for a single-feed to achieve a dual band frequency for WiMAX application with circular polarization (CP) is reported in [12]. In the single layer with asymmetrical slot and two truncated corners the antenna operated in dual band. The radiation patterns demonstrate well across polarization rejection with low back lobe radiations in directional orientation. The antenna has a small size as well as a good impedance matching bandwidth and is easy to fabricate. The compact microstrip antenna showed a good radiation characteristic with an impedance bandwidth of 246 MHz at the frequency of 5.7 GHz WiMAX and WLAN applications with a gain of 4dB at 5.7GHz.

This paper is organized as follows: Section II presents the proposed antenna geometry, whereas the antenna simulation results and discussion are presented in section III. In the end, Section IV concludes the paper.

II. ANTENNA DESIGN GEOMETRY

In this part, the design steps together with the design equations are presented. The parameters of the proposed circular patch antenna array are calculated at 5.8 GHz. Since the dielectric substrate has a significant impact on both the radiation pattern and the impedance of a micro-strip antenna. It is important in that case to choose right substrate material for an antenna.

Besides other electrical properties, dielectric constant and loss tangent are the most significant characteristics when selecting a substrate. The size of an antenna is inversely proportional to the dielectric constant of a substrate. The proposed antenna dimensions are 35 x 76 mm^2. The thickness of the substrate material is 1.757 mm with a tangent factor of 0.0012 while having a dielectric constant of 2.33. The proposed antenna geometry is shown in Figure 1.

A patch is just a conducting plane with any shape. The shape depends on the antenna design. The proposed antenna is designed with a circular patch, since it obtains less space compared to other patches. The most commonly used patches are square, rectangular and triangular.

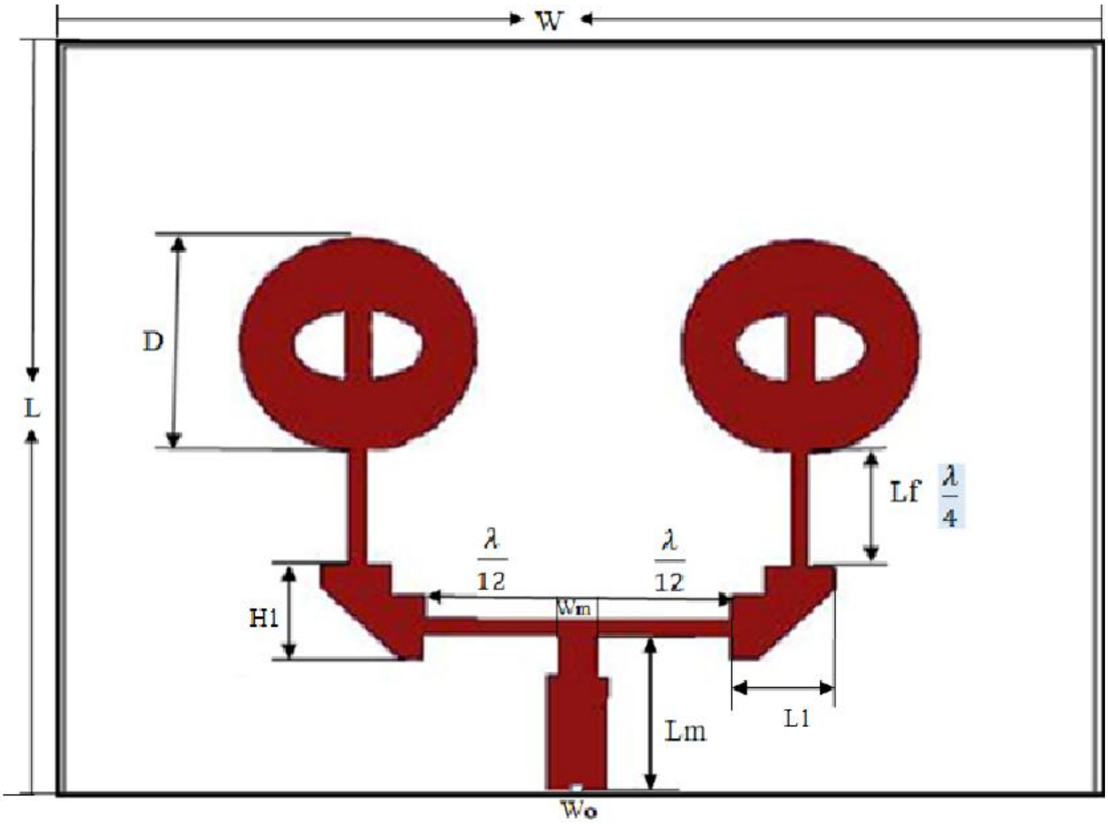

Figure 1: Proposed Antenna Array Geometry

It is necessary to determine the radius of the patch for the desired resonant frequency for the dominant TM_{10} mode by solving

$$r = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon r F}\left[In\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{\frac{1}{2}}}$$

Where,
r= Radius of the circular patch
ε_r = Dielectric constant of the substrate
c= Speed of light
h= Height of Substrate

Figure 2 shows the current distribution of the proposed antenna. In the figure, 6 A/m is evident in the feeding point. A similar result is observed at the top layers of the patches of the antenna array.

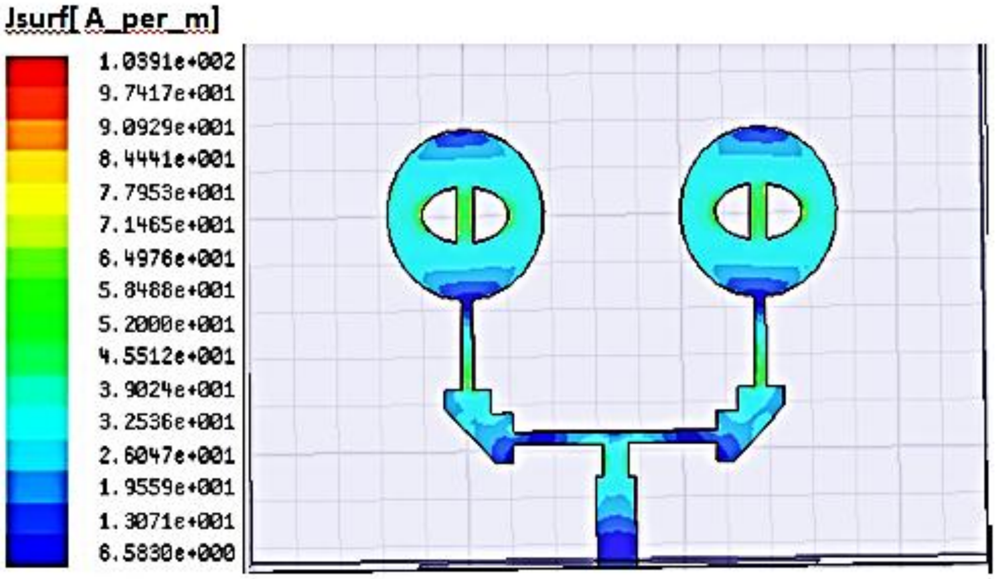

Figure 2: Simulated Current Distribution in the Patch

The width and the length of the proposed antenna have been optimized to 35 × 76 $mm^2$and this increases the impedance bandwidth and reduces the return loss. Complete specifications of the proposed design are given in Table1.

Table 1: Specifications of the Proposed Antenna

Parameter	Proposed Design
Length of the substrate, L	35mm
Width of the substrate, W	76mm
Space between two elements, Wps	30 mm
Radius of the circular patch antenna, r	9mm
Width of the Transmission Line	1.32 mm
Resonant Frequency	5.8 GHz
Substrate Materials (Duroid)	5880
Dielectric Constant, ε_r	2.2
Loss Tangent, Tan δ	0.0009
Substrate Thickness, *h*	1.757 mm
Diameter of circular patch antenna, D	18 mm
Length of the Feed line, Lf	$\frac{\lambda}{4}$
Width of the microstrip feed line, Wo	4.6mm
Conducting width strip, G	2mm
Length the bend of microstrip line, L1	7.9mm
Height of the bend of microstrip line, H1	7.9mm

III. SIMULATION RESULTS

The proposed antenna is simulated at 3.5 GHz. The proposed antenna is designed and simulated in the commercially available Ansoft high-frequency structure simulator (HFSS) software.The performance of the proposed antenna isanalysed using the following parameters.

a) Return Loss (S_{11})
b) Bandwidth (BW)
c) VSWR
d) Radiation Pattern
e) Gain
f) Directivity

Return loss is the ratio of the power fed to an antenna to the power reflected back to the feed point. Thus, the power fed to an antenna should be absorbed rather than being reflected, which obviously produces a power loss. However, the best value of return loss must be negative infinity if the power is absorbed and must be equal to zero if the power is reflected. Usually, return loss helps in determining the resonant frequency of an antenna.

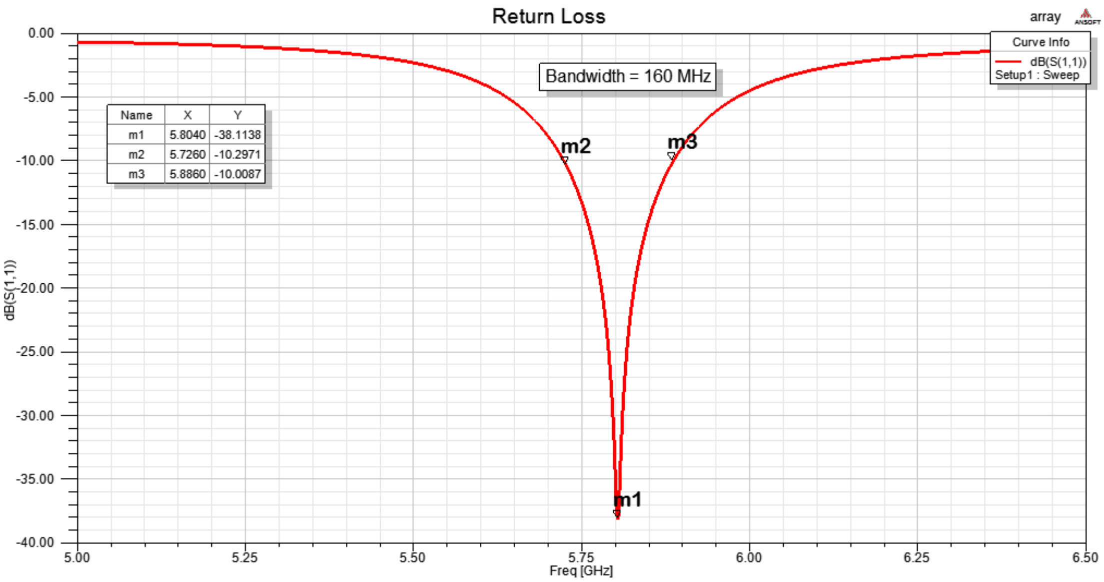

Figure 3: Return Loss of the Proposed Antenna Array

Figure 3 shows the simulation results of return loss of-38.11 dB at 5.8 GHz. It can be observed that a bandwidth of 160 MHz is achieved. The operating bandwidth of the IEEE 802.11ac WiMAXstandard is 140 MHz. Thus the proposed antenna meets the required standard.

Usually, the VSWR helps in determining the impedance matching of an antenna with the transmission line and this should be a small value and must be near 0 dB or near to unity. In Figure 4 a VSWR of 0.29 dB (1.06) at 5.8 GHz is evident.

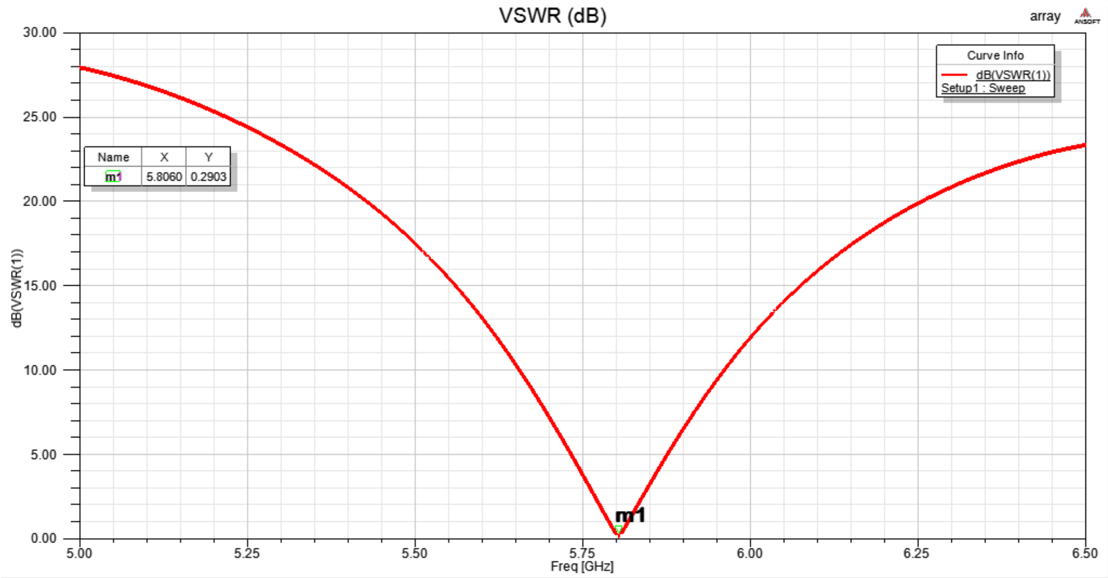

Figure 4: VSWR of the Proposed Antenna Array

Figure 5 illustrates that the 3D simulated gain of the proposed antenna array. It can be observed that the maximum gain achieved is 9.948 dB.

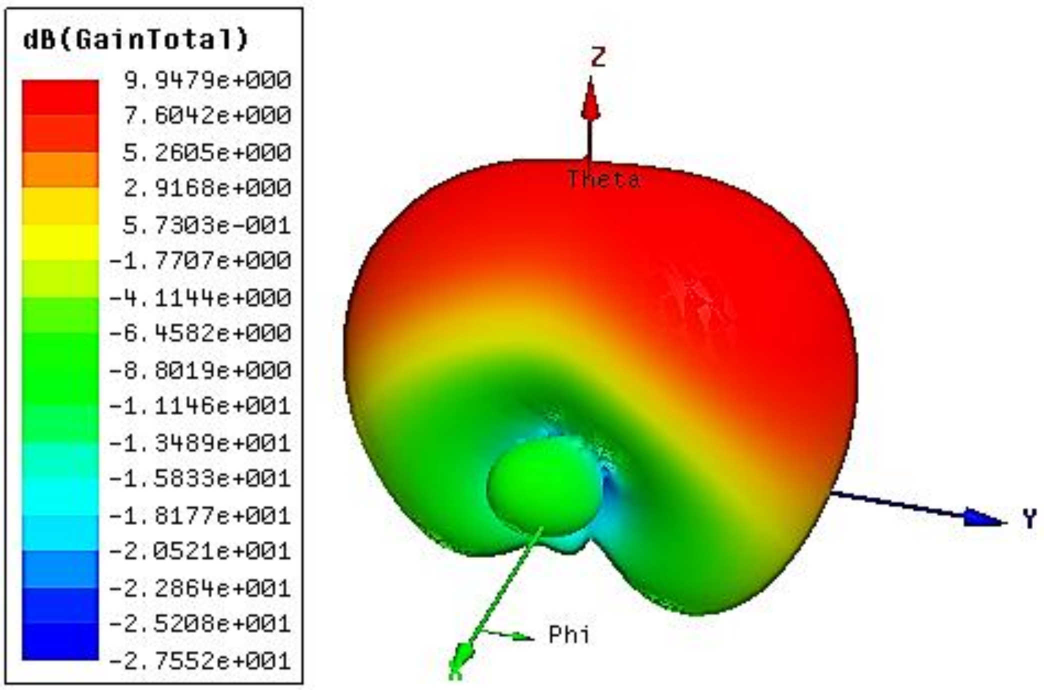

Figure 5: 3D Simulated Gain

Figure 6 demonstrates the radiation pattern of the antenna. It can be seen that the proposed antenna exhibits a directional radiation pattern. The figure also shows that the antenna has a back lobe which radiates at -15.74 dB which is a very low radiation power compared to the front lobe. The antenna radiates a power of -10.11 dB at -90° and -10.55 dB at 90°. The antenna has a beam width of 40°.

The directivity for 5.8 GHz frequency is 10.01 dB as shown in Figure 7. The antenna has a Front-to-Back ratio of more than 22 dB.

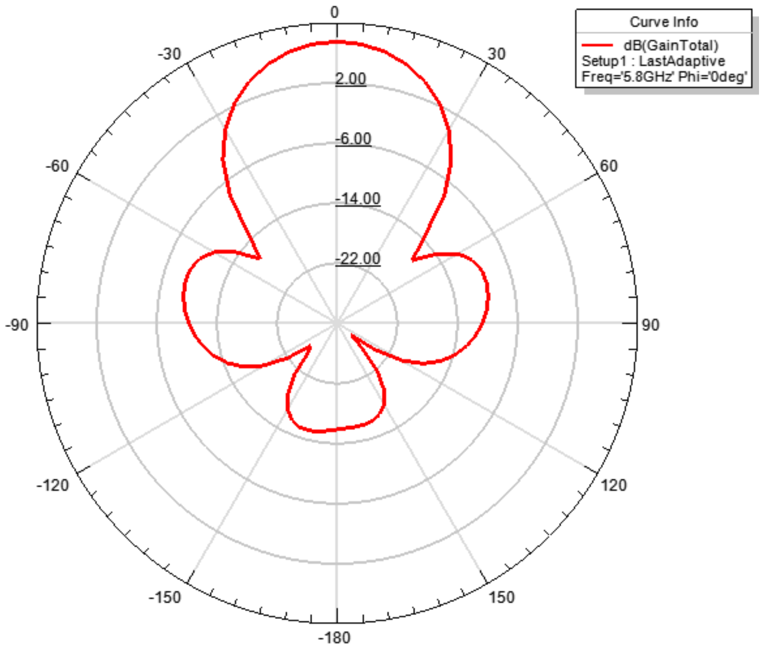

Figure 6 : 2D Radiation Pattern

Table 2 presents the summary of the simulation results of the proposed antenna. The proposed antenna is reduced in size by 22 % with the dimensions of 35x 76 mm^2 compared to the existing antenna [10].

Table 2: Simulation Results of Proposed Antenna Array

Parameters	**Proposed Antenna**
Resonant Frequency	5.8 GHz
Dimensions	35 x 76 mm^2
Return loss	-38.11 dB
VSWR	1.06 (0.29 dB)
Gain	9. 95 dB
Directivity	10.01 dB
Front-To-Back ratio	24 dB
Beam width	40°

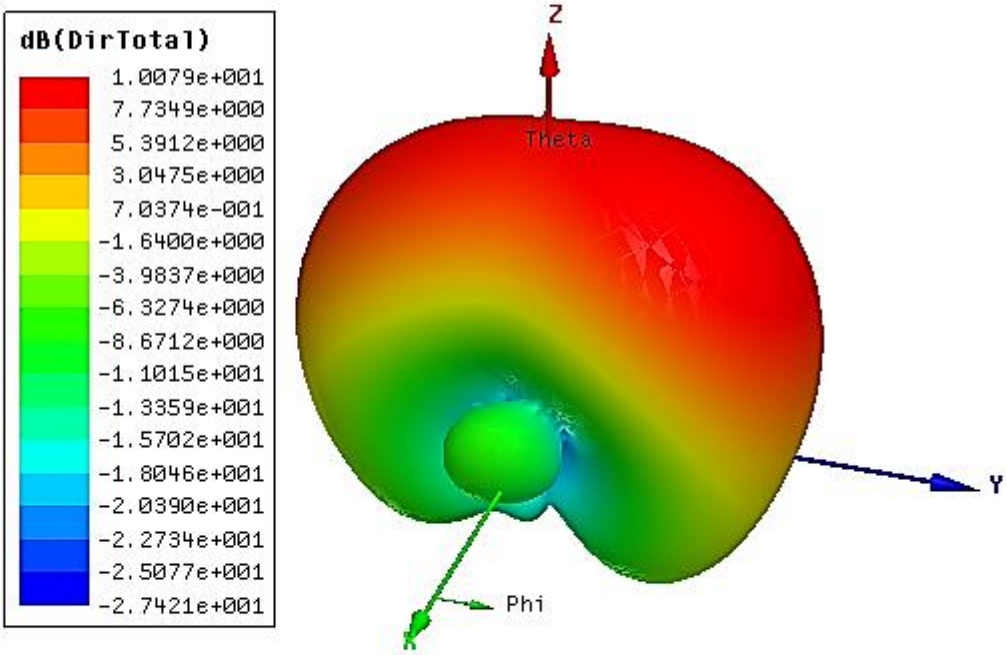

Figure 7: 3D Simulated Directivity

Table 4: Performance Evaluation of the Proposed Antenna

S.No	Parameter	Proposed Design	ExistingDesign [10]	Remarks
1.	Size	35x76 mm^2	40x85 mm^2	21% Reduce
2.	Return loss (dB)	-38.11	-30.79	19% Enhance
3.	VSWR	1.06	1.09	3% Enhance
4.	Gain (dB)	9.95	9	10.55% Enhance

In Table 4 the performance evaluation of the proposed antenna against the existing antenna [10] is presented. The results clearly indicate that the return loss of the proposed antenna is -38.11 dB compared to published results in the literature [10] which is -30.79 dB an improvement of 19%. Similarly, a 10.55% enhancement is evident if we compare the antenna gain. Moreover, the VSWR of the proposed antenna is 1.06 compared to 1.09 which is 6.86% improvement.

IV. CONCLUSION

In this paper a 2×1 enhanced circular microstrippatch antenna array at 5.8 GHz is presented. The proposed antenna is reduced in size and unveils improved performance characteristics. The gain and the directivity of the antenna is more than 9 dB. The antenna achieved a return loss of less than -35 dB, aVSWR less than 1.1 and more than 20% size reduction.The antenna exhibitsa directional radiation pattern. The enhanced features make the proposed antenna suitable for WiMAX and other applications operatingat 5.8 GHz.

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