Mühendislik Bilimleri ve Tasarım Dergisi
9(4), 1296 – 1301, 2021
e-ISSN: 1308-6693

Journal of Engineering Sciences and Design
DOI: 10.21923/jesd.676705

Araştırma Makalesi Research Article

DESIGN OF CIRCULAR SLOTTED RECTANGULAR MICROSTRIP PATCH ANTENNA WITH DUAL-RESONANCE FOR WLAN/WIMAX APPLICATIONS

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Keywords

Microstrip Patch Antenna, Wideband, Dual Resonance, WLAN, Circular Slotted.

Abstract

In this work, a design for enhancing bandwidth of a dual-resonant circular slotted patch antenna for 2.4-3.5 GHz WLAN/WiMAX applications is proposed and tested. The designed antenna is a modified form of the rectangular patch antenna consisting of three identical circular slots in antenna surface and it printed on an FR-4 substrate. This antenna has two different operating frequencies, with center frequencies of 2.592 and 3.338 GHz. Classical microstrip antennas yield a maximum bandwidth of about 8%. By incorporating slots in antenna, the bandwidth of the antenna is improved. The fractional bandwidth at 2.592 GHz is 50.9% and at 3.358 GHz is 39.5%. The proposed antenna is simulated, fabricated and tested. Measured results showed good agreement with the simulated results. The gain of the antenna is 2.169 dB at 2.59 GHz and 2.175 dB at 3.338 GHz.

WLAN UYGULAMALARI İÇİN ÇİFT REZONANS FREKANSINDA ÇALIŞAN DAİRESEL YARIKLI DİKDÖRTGENSEL MİKROŞERİT YAMA ANTEN TASARIMI

Anahtar Kelimeler

Mikroşerit Yama Anten, Genişbant, Çift Rezonans, WLAN, Dairesel Yarık.

Öz

Bu çalışmada, 2,4-3,5 GHz WLAN/WiMAX uygulamalarında bant genişliği arttırımı için çift rezonanslı dairesel yarıklı yama anten önerilmiş ve analiz edilmiştir. Tasarlanan anten, dikdörtgensel yama antenin yüzeyinden 3 tane dairesel yarık oluşturulması ile elde edilmiş ve anten FR-4 malzemesi kullanılarak ürettirilmiştir. Bu anten, merkez frekansları 2,592 GHz ve 3,338 GHz olmak üzere iki farklı çalışma frekansına sahiptir. Klasik mikroşerit antenlerin maksimum oransal bant genişliği %8 civarındadır. Klasik mikroşerit antene dairesel yarıkların açılması ile oransal bant genişliği 2,592 GHz merkez frekansında %50,9 arttırılmış olup, 3,338 GHz merkez frekansında ise %39,5 arttırılmıştır. Antenin kazancı 2,592 GHz'de 2,169 dB ve 3,338 GHz'de 2,175 dB olarak bulunmuştur. Önerilen antenin simülasyonu, üretimi ve analizleri yapılmıştır. Ölçüm sonuçlarının simülasyon sonuçları ile tutarlı olduğu gözlenmiştir.

Alıntı / Cite

Bayer Keskin, S. E., Güler, C., (2021). Design of Circular Slotted Rectangular Microstrip Patch Antenna with Dual-Resonance for WLAN/WiMAX Applications, Journal of Engineering Sciences and Design, 9(4), 1296-1301.

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Makale Süreci / Article Process	
Başvuru Tarihi / Submission Date	17.01.2020
Revizyon Tarihi / Revision Date	15.09.2021
Kabul Tarihi / Accepted Date	22.09.2021
Yayım Tarihi / Published Date	20.12.2021

1. Introduction

In recent years, it has become indispensable for mobile applications and wireless communication to operate multiple features at the same time. There is increasing demand for antennas having broa dBand and multiple resonance frequencies in recent years. The design of lightweight, low cost, high bandwidth microstrip antennas is essential for wireless devices to be able to transmit images, speech and data in various frequency bands at the

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same time. The patch antenna idea appeared to be proposed by Deschamps in the early 1950s. A few years later, a microstrip antenna patent was issued by Gutton and Baissinot. In the 1970s, thin, surface-compatible microstrip antennas were produced for military applications such as missiles and space shuttles. Microstrip antennas have many advantages such as being small in size, easy adaptation to electronic circuits, low power consumption, high performance, low cost, mechanical durability and dual frequency applications. Because of these advantages, they have become a widely used antenna type in almost all areas of wireless communication. However, microstrip antennas have disadvantages of narrow bandwidth and low efficiency as a result of various losses. Much of the development work in microstrip antennas has trying to overcome these problems, in order to satisfy systems requirements.

2. Literature Review

Data transmission in various frequency bands of wireless devices is achieved by using a multi-band or broa dBand antenna. Broa dBand and multiple resonance frequencies in microstrip patch antennas have recently been in increasing demand.

There are many studies in the literature covering the WLAN applications of microstrip patch antennas (Armağan vd., 2016; Yu vd., 2012; gemio vd., 2009). Yassin et. al. (2013) examined dual band rectangular microstrip patch antenna operating at 2.4 GHz and 3.5 GHz frequency. Return loss is -22 dB and -27 dB, bandwidths are 65 MHz and 50 MHz at 2.4 GHz and 3.5 GHz, respectively. Wu et. al. (2013) presented a C and T-shaped patch and a dual-band patch antenna consisting of a 50ohm microstrip line feeding these patches for wireless communication systems. The antenna is operating between 2.5 GHz and 3.5 GHz frequency. -10 dB impedance bandwidth is 200 MHz at 2.5 GHz (2.50 GHz-2.70 GHz) and 800 MHz at 3.5 GHz. Designed antenna is suitable for using Multi Input Multi Output (MIMO) systems. Rosaline et. al. (2015) suggested a microstrip antenna design with complementary split ring resonators (CSRR) developed from hexagonal microstrip patch antenna. The antenna operates at GSM 1.8 GHz and WLAN 3.5 GHz frequency bands. Antenna gain is 0.62 dBi and 1.07 dBi at 1.8 GHz and 3.5 GHz, respectively. Kumari et. al (2012) have designed a triangular two-element dielectric resonator antenna (DRA) array for wireless local area network (WLAN) and microwave access (WiMAX) applications. Impedabce bandwidth of the suggested antenna is 2.16-2.94 GHz for 2.4 GHz WLAN applications and 3.22-3.63 GHz for 3.5 GHz WiMAX applications. Liu et. al (2016) presented a new design with linear polarization for the single-feed double-layer dual-band patch antenna. The antenna has E-shaped and U-shaped patches of 42 mm and 31 mm. Suggested antenna impedance bandwidths are 26.9% and 7.1%, respectively. Gupta et. al. (2015) suggested meander slot microstrip patch antenna for dual-band applications at 2400 MHz and 3500 MHz. Suggested antenna bandwidths are 177.4 MHz and 146.6 MHz and gains are 2.44 dB and 3.35 dB at 2400 MHz and 3500 MHz, respectively. It is observed that the slits on the patch and partial ground planes increased the bandwidth and gain on the microstrip patch antennas. (Değirmenci vd.,2014; İsmail vd., 2015; Sharma vd., 2012).

In this paper, a circular slotted microstrip patch antenna with dual-resonance is proposed and designed for. Wireless Local Area Network (WLAN, 2.4-3.5 GHz) applications as well as Worldwide interoperability for Microwave Access (WiMAX –IEEE 802.16e). The frequency range of the designed antenna is between 2.26 GHz and 3.58 GHz (1.32 GHz) and has a dual resonance frequency of 2.592 GHz and 3.338 GHz. Fractal Bandwidths are 50.9% at 2.592 GHz and 39.5% at 3.338 GHz resonance frequency. The proposed antenna designed and simulated using CST Microwave Studio. Numerical analysis results such as resonance frequency, bandwidth, directional gain, radiation efficiency and surface current distributions are included. Table 1 shows the comparison of the performance of similar antennas with the antenna proposed in this study. It is observed that the proposed antenna enhances the bandwidth.

Table 1. Comparison between different antenna designs.

Study	Dimension (mm^3)	Operation Frequency	Bandwidth (<-10 dB)
(Yassin et. al., 2013)	4.6×36×1.6	2.4 GHz and 3.5 GHz	65 MHz and 50 MHz
(Wu et.al., 2013)	95×60×0.8	2.5 GHz and 3.66 GHz	200 MHz and 800 MHz
(Gupta et.al., 2015)	37.75×31.75×1.5	2.4 GHz and 3.5 GHz	177.4 MHz and 146.6 MHz
(Kumari et.al., 2012)	60×56×1.6	2.4 GHz and 3.5 GHz	780 MHz and 410 MHz
(Liu et.al., 2016)	60×45×1.5	2.4 GHz and 3.5 GHz	700 MHz and 260 MHz
Proposed Antenna	**60×60×1.6**	**2.4 GHz and 3.5 GHz**	**1320 MHz (2.26-3.58 GHz)**

3. Material and Method

Microstrip patch antennas are formed by placing the radiating plane on the substrate in the desired geometry. The patch and ground plane generally have uniform geometries, but non-uniform geometries are also used. The substrate used in the proposed antenna is a FR-4 material having a thickness of 1.6mm, dielectric permeability of 4.3 and loss tangent of $\tan\delta = 0.019 \cong 0.02$. The patch is excited via $50\,\Omega$ microstrip transmission line. Designed dual-resonance microstrip patch antenna has partial ground structure and circular slots on the rectangular patch to improve the bandwidth. Figure 1 shows the geometry of the proposed antenna. Here, L_d is substrate length, W_d is substrate width and also ground width, L_p is patch length, W_p is patch width, L_f is feed line length, W_f is feed line width, $C_1 = C_3, C_2 = C_4, C_5$ and C_6 are angular length of circular slots, L_g is ground length, a is gap width of inset feed and x is gap length of inset feed.

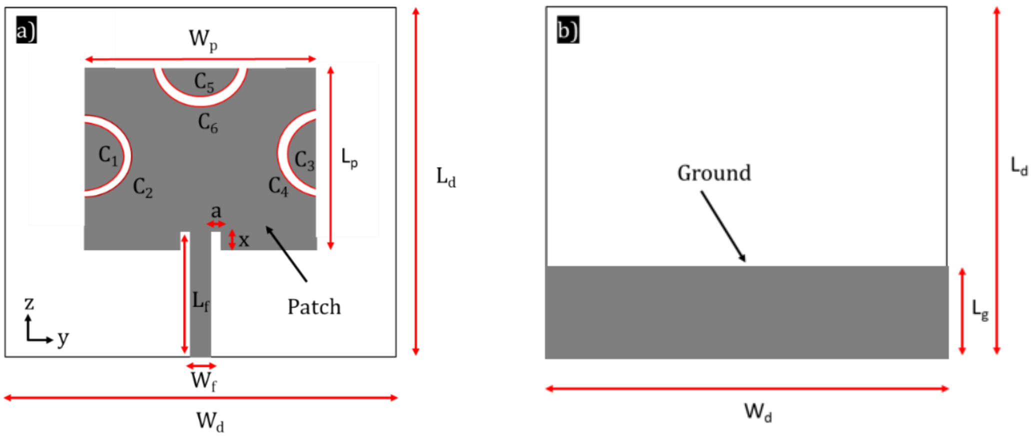

Figure 1. The structure of the proposed antenna, a) front view, b) rear view.

The dimensions of the proposed microstrip patch antenna is given in Table 2.

Table 2. Dimensions of the proposed antenna.

Parameter	W_d=L_d	W_p	L_g	W_f	C_2=C_4	C_1=C_3
Value (mm)	60	28	15	3	19.98	13.69
Parameter	L_f	a	x	L_p	C_5	C_6
Value (mm)	21.86	1.5	4.36	25	11.59	17.93

The antenna is built on a low-cost substrate 60 mm long and 60 mm wide. The structure is fabricated using the LPKF (S63) PCB prototyping machine on a low-cost FR4 substrate (loss tangent = 0.02) with 1.6 mm thickness and 4.3 relative permittivity. Fabricated antenna is shown in Figure 2.

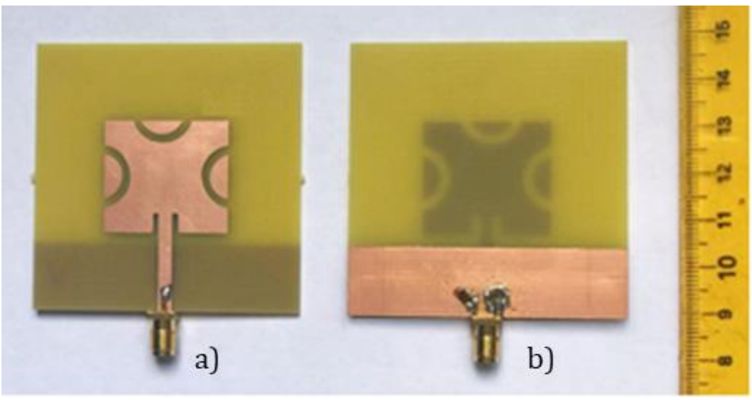

Figure 2. Fabricated antenna a) front view, b) rear view.

In Figure 3, the S-parameter (S11) versus frequency curve for the proposed antenna design is presented. Simulations are carried out by CST Microwave Studio. To validate to results, the fabricated antenna is measured using the Rohde&Schwarz vector network analyzer (VNA) with model no. ZVA40. According to the results in Figure 3, operating frequency range of the microstrip patch antenna with slots added rectangular is almost from 2.267 GHz to 3.587 GHz.

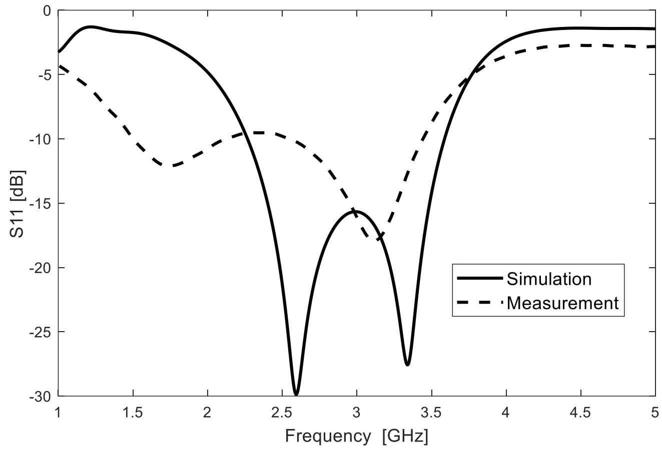

Figure 3. The simulation and measurement results for reflection coefficients of the proposed microstrip patch antenna.

4. Experimental Results

Figure 4 shows the gain (dB) of the proposed microstrip patch antenna. The antenna's gain has the tendency to increase with the increase in frequency within the UHF RFID band. From the figure it is noticed that the gain of antenna varies between 2.065 to 2.24 dB within the operating frequency band and with the maximum gain of 2.24 dB at 3.0736 GHz. The lowest gain is found at the 2.26 GHz frequency with a 2.065dB. Designed antenna gain at resonance frequencies are 2.169 dB at 2.592 GHz and 2.175 dB at 3.338 GHz.

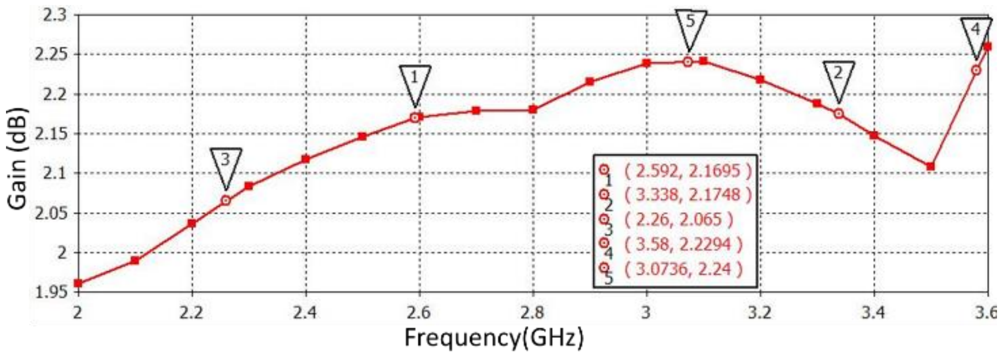

Figure 4. Gain (dB) versus frequency.

The 3D gain of the designed antenna is presented in Figure 5 a) at 2.592 GHz and b) 3.338 GHz. Designed microstrip patch antenna provides a maximum directive gain about 2.169 dB at 2.592 GHz and 2.175 dB at 3.338 GHz. Both resonance frequencies have nearly same gain values.

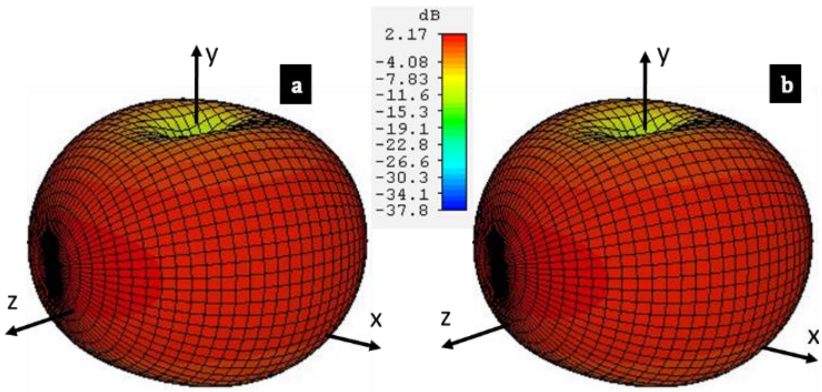

Figure 5. 3D Gain plot of the proposed antenna at a) at 2.592 GHz and b) at 3.338 GHz.

The simulated radiation pattern graphs of the proposed antenna are shown in Figure 6.

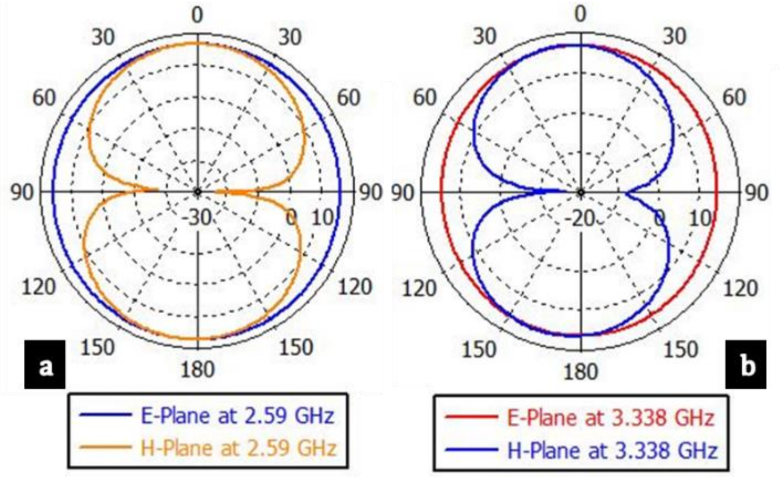

Figure 6. Simulated radiation patterns in the E and H planes for the proposed antenna (a) at 2.59 GHz and (b)at 3.338 GHz

Figure 7 shows the simulated current distribution in circular slotted microstrip patch antenna at 2.592 GHz and 3.338 GHz resonance frequencies. The current distribution is dense and well spread. Efficiency of the antenna depends on the current distribution. Designed circular slotted microstrip patch antenna surface current amplitude is 150 $\mu A/m$ at 2.592 GHz and 151 $\mu A/m$ at 3.338 GHz.

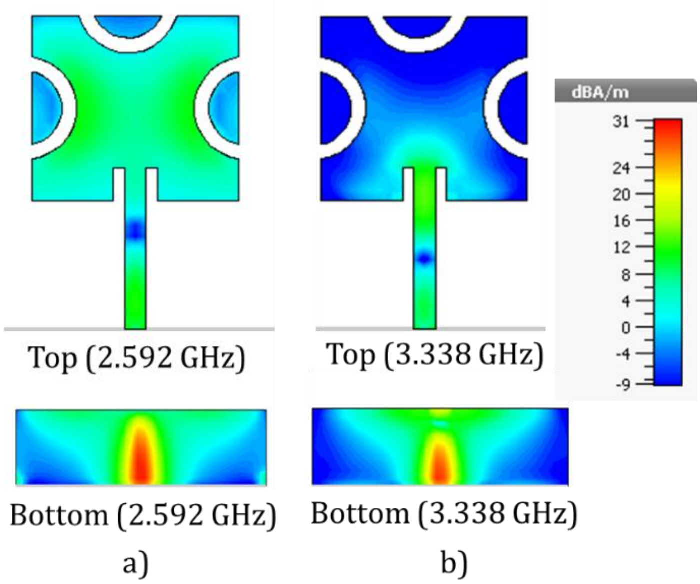

Figure 7. Surface currents of the proposed antenna a) for 2.592 GHz, b) for 3.338 GHz.

5. Results and Discussion

Microstrip antenna has become one of the most preferred antenna types in communication systems as it has small size, easy adaptation to electronic circuits, low cost and operating at multiple frequencies. In this study, a new antenna design has been proposed to meet the need for microstrip patch antenna designs such as broa dBand and multiple resonance frequencies arising from the reasons such as increasing the data transfer rate and the continuous data transfer WLAN/WiMAX band applications which are widely used in wireless communication systems. The designed antenna is a modified form of the rectangular patch antenna consisting of three identical circular slots in the patch surface. Proposed antenna has two different operating frequencies, with center frequencies of 2.592 and 3.338 GHz and by modifying antenna with slots, bandwidth of the antenna is improved by 50.9% and 39.5% at these resonance frequencies, respectively. The numerical analysis of the proposed antenna such as reflection coefficients (S11 parameters), directive gain, surface current and radiation patterns examined by using CST Microwave Studio. Return loss of the proposed antenna is -29.87 dB at 2.592 GHz and -27.57 dB at 3.338 GHz and 10 dB bandwidth is 1.32 GHz. Gain values are varying between 2.06 dB and 2.24 dB within the operating band. The proposed antenna has proven to be able to achieve high performance and is suitable for wireless communication systems.

Conflict of Interest

No conflict of interest was declared by the authors.

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