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Gain Improvement of Dual-Band Circular Monopole Antenna for 2.45/5.5 GHz WLAN Applications

***Abstract**. This paper presents a gain improvement of dual-band antenna for 2.45/5.5 GHz WLAN applications. The radiating element of the proposed antenna consists of a circular disc monopole with circular-slot laid on FR-4 substrate and backed by a partial ground plane. This partial ground plane is modified to improve its radiation performance. This proposed antenna operates over the frequencies of 2.4-2.485 GHz and 5.15-5.825 GHz with nice radiation characteristics and magnitude of S_{11} better than -10 dB. An EM simulator has been used in the design and simulation. In addition, an experimental validation was set and measured to compare with the simulated results. All numerical results will be reported and discussed in the paper.*

Streszczenie.** W artykule opisano dwupasmową antenę do pasma2.45/5.5 GHz I sici WLAN. Antena składa się z okrągłego dysku i okrągłej szczeliny. Częściowo uziemione podłpoże poprawia właściuwości radiacyjne.* ***Dwupasmowa antena cyrkularna na pasmo 2.45/5.5 GHz

Keywords: gain improvement; dual-band antenna; circular monopole antenna; WLAN applications.
Słowa kluczowe: . dwupasmowa antena, sieci bezprzewodowe, okrągły promiennik

Introduction

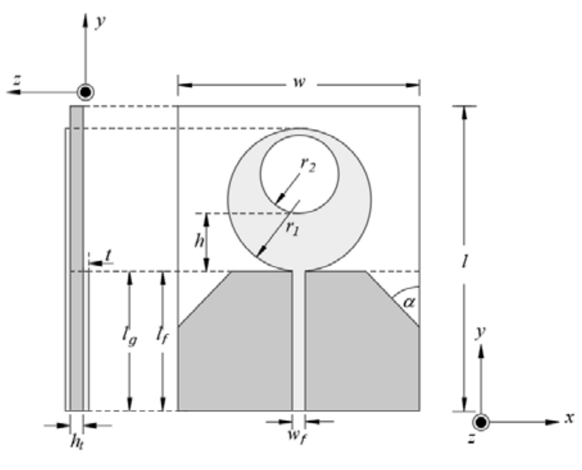
With Rapid developments of modern wireless communications, various microwave technologies have been utilized for different applications, which make the microwave spectrum more crowded. Wireless fidelity has transformed in to the standard for wireless local area network (WLAN) communications in the 2.45 and 5.5 GHz ISM bands, with the frequency ranges from 2.4 to 2.485 GHz as well as 5.150–5.350 GHz, 5.470–5.725 GHz, and 5.725–5.850 GHz [1]. For system flexibility and feasibility, antennas that are capable to serve in both of the specified operation bands are highly attracted. For this reason, dual-antennas are promoted to overwhelm the 2.45- and 5.5 GHz WLAN bands [2]-[10]. A dual-band antenna can be usually accomplished by utilizing two types of single-frequency antennas for each band [8], and taking a dual-frequency antenna for two separate bands [5], [9]. For the two types of single-frequency antennas, two external feeding networks must be come up with these individual dual-band antennas, which probably entail some structural sophisticates into applications [8]-[9].

As mentioned above, an element to make up a dual-band antenna is more suitable to employ a dual-frequency antenna. There are many techniques to design for WLAN dual-band, such as using quarter-wavelength resonant slots in different shapes, coplanar fed, parasitic elements, and defected ground plane [5]-[13]. Latterly, many researchers adopt an attention on printed slot antennas (PSA), since wide-slot antennas have two orthogonal resonance modes, which are combined to form a wide impedance bandwidth [14]. As reported for increasing impedance bandwidth, antennas with various shapes like circle, ellipse, and triangle were introduced [15]. In our previous work [12], we presented the design and implementation of dual band with partial ground plane (PGP); nonetheless, its gain is not high. Hence, a technique to enhance the radiation performance of a microstrip-fed circular disc monopole with circular-slot (CDMCS) is introduced in this paper by modifying its partial ground plane (MPGP) with diagonal cuts at the top corners (DCTCs). Applications of corner cut technique have been previously applied to improve the impedance bandwidth and radiation properties for patch antennas [6], [16]. Since, this affects to the flow of surface currents especially around its edges of PGP, thus more currents flow on the radiator. The simulation results of proposed antenna comparing with the measurement one will be report in the rest of the paper.

Antenna design

The proposed dual-band antenna is depicted in Fig. 1. Its structure consists of a radiating circular patch and modified partial ground plane. For the radiating section, a circular disc monopole (CDM) of radius r_1 together with a circular-slot of radius r_2 is printed on a coper layer which supported by a FR-4 substrate of thickness 1.6 mm and relative permittivity 4.3.

a)



b)

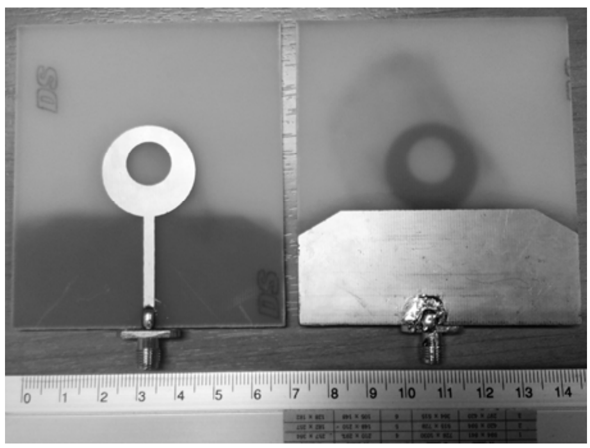


Fig.1. Geometry of the proposed antenna: (a) model and (b) prototype

The length and width of dielectric substrate denote *l* and *w*, respectively. Using (1), the width of the microstrip feed line is calculated and fixed at w_f = 2.6 mm to obtian 50 Ω impedance **[17].** While the length of feeding line l_f is set around $\lambda_L/4$, where λ_L is the wavelength of lower band frequency. This feed line is laid on the same side of radiating CDM. Furthermore, a circular-slot of radius r_2 is included on the radiating CDM to improve the impedance matching. On the opposite side of the substrate, a PGP with a length l_g covers the feeding section. In this work, the length l_g is designed to be the same length as a feeding line l_f.

One more parameter that affects the dual-band resonant frequency is a gap *h* between lower edge of circular-slot and the feed point attached the radiating CDMCS.

(1) $$Z_0 = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left(\frac{5.98h_t}{0.8w_f + t}\right)$$

where h_t denotes the height of substrate, and *t* is the thickness of coper layer. In this paper, *t* is equal to 0.035 mm. In addition to the feeding line, the radius r_1 of CDM is initially selected by calculating (2) [17].

(2) $$f_r = \frac{72}{2.25r_1} GHz$$

where, f_r is the lower-band resonance frequency that is 2.45 GHz. From (2), r_1 of 13 mm is firstly selected in the beginning and then analyzed to get the appropriated one [12]. All prospered parameters are yielded by using an electromagnetic simulation tool, and tabulated in Table 1. To validate the simulation, a prototype of the proposed CDMCS with MPGP as shown in Table 1 was built up and tested using an E5071C network analyzer.

Table 1. The parameters of the designed antenna

Parameters	Physical size (mm.)	Parameters	Physical size (mm.)
w	70	r_1	12
l	80	r_2	6
l_g	29	*h*	8
l_f	29	w_f	2.6
h_t	1.6	α	60°

Impedance and radiation characteristics

This section reveals the simulation results of designed antenna as tabulated in Table 1. The proposed CDMCS is printed on the top layer of copper thickness of 0.035 mm and supported by the FR4 substrate of height 1.6 mm, and ε_r of 4.3. The design initially begins with the appropriated parameters CDM of radius r_1 of 12 mm with 50 ohms fed line of length 29 mm and width w_f of 2.6 mm, that achieved from our previous work [12]. To get a dual-band antenna with an improving impedance matching for 2.45/5.5 GHz WLAN, the circular-slot of radius 6 mm is included [12]. It was found that this presented antenna with partial ground plane ($\alpha = 0^\circ$) provided a magnitude of S_{11} better than -10 dB for both two bands with the maximum gains of 2.35 dBi and 3.83 dBi for the lower (2.4-2.485 GHz) and upper bands (5.15-5.825 GHz), respectively, as shown in Fig. 2.

To increasingly improve its radiation performance, a technique of DCTC of PGP with the angle of α is supplemented and investigated. Apparently, cutting the top edges of PGP with the angle α affects the resonant frequency of both lower and upper bands. As seen in Fig. 3, the larger α shifts down the resonant frequencies of the two bands, as well as increases the impedance bandwidth. Note that the current distributions of proposed CDMA with and without modified ground planes are different especially around the edge of their ground plane. Cutting its corner affects the surface current distribution along the feeding line to the radiating patch flowing more uniform and more strengthen. As the results, its radiation performance gets better. Moreover, the effect of DCTC of PGP to the antenna gain is illustrated in Fig. 4. Obviously, the larger α provides a slightly higher gain. As shown in Fig. 4, the maximum gains of 2.66 dBi and 4.0 dBi are yielded for the lower and upper bands, as well as the resonant frequencies occur around 2.45 GHz and 5.5 GHz (see Fig. 3), when α is equal to 60 degree.

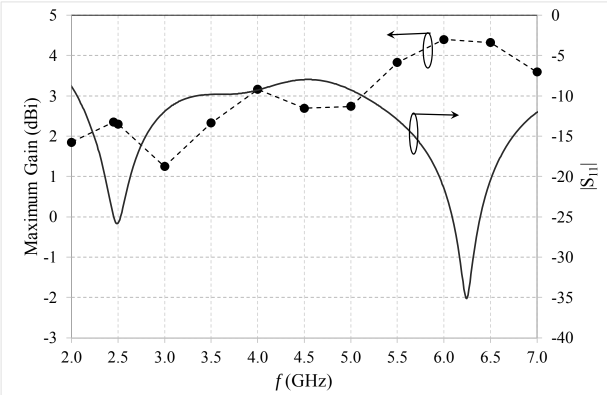


Fig.2. Maximum gain of proposed antenna for $\alpha = 0^\circ$

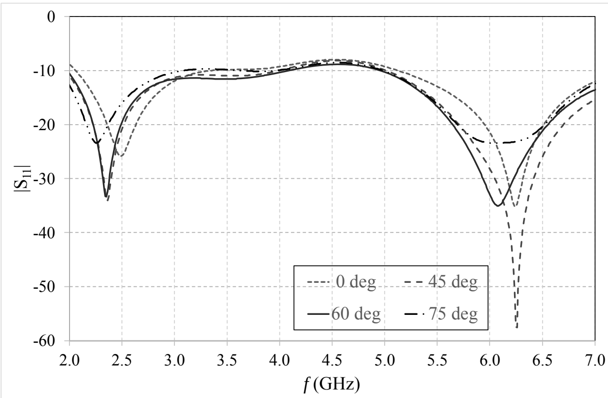


Fig.3. $|S_{11}|$ for various α

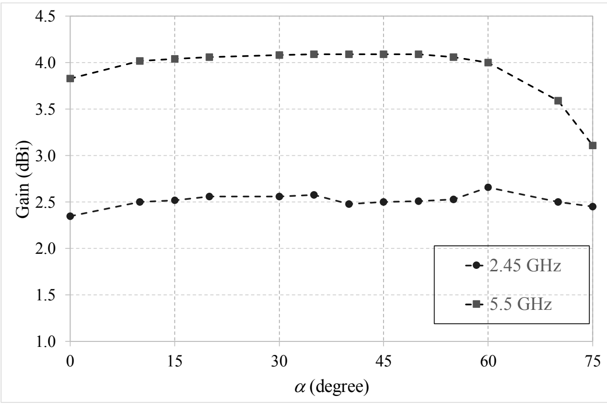


Fig.4. Maximum gain for various α

For validation the simulation, a prototype of proposed antenna was invented and tested. Figure 5 shows the simulated and measured $|S_{11}|$ versus the frequency ranging from 2 GHz to 7 GHz. Apparently, simulated $|S_{11}|$ is in well acceptance with measured one, and they are less than -10 dB over the frequencies range from 2.02 GHz–3.97 GHz and 2.08 GHz–3 GHz covering the lower band for the simulation and the measurement, respectively. Similarly the simulated and measured $|S_{11}|$ of the upper band, they are better than -10 dB covered the frequencies range from 5.02 GHz–7 GHz, and 5.14 GHz–7 GHz, respectively.

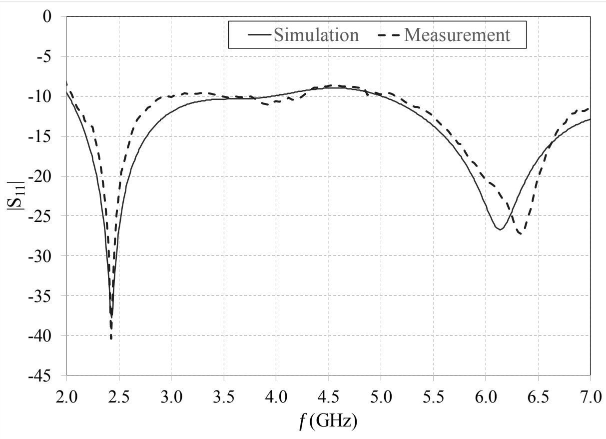
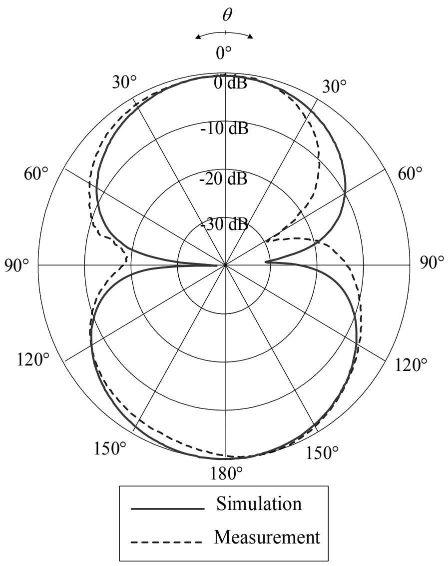


Fig.5. The simulated and measured $|S_{11}|$ versus frequency

a)



b)

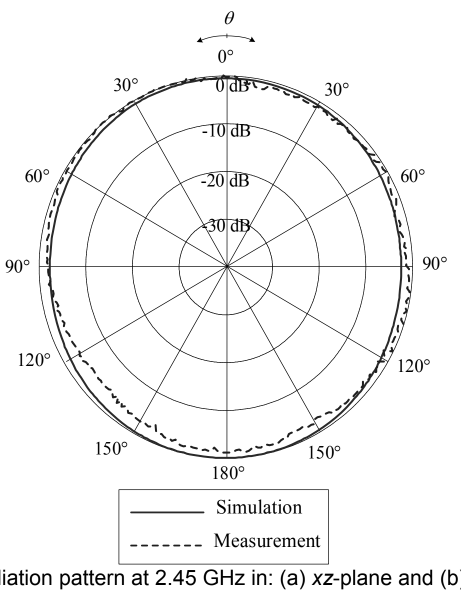
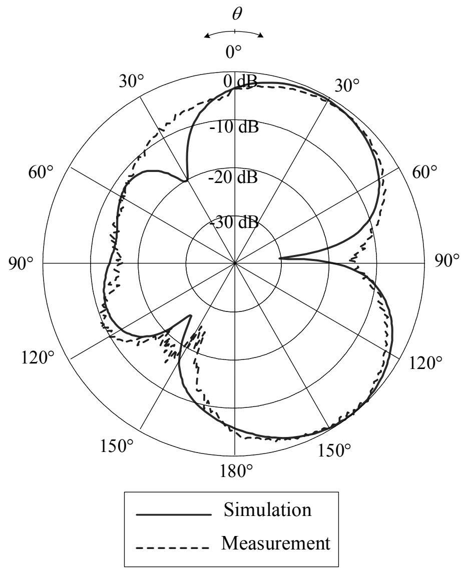


Fig.6. Radiation pattern at 2.45 GHz in: (a) *xz*-plane and (b) *yz*-plane

In addition to the impedance matching, the radiation properties are also confirmed. The plot of simulated and measured radiation patterns in *xz*- and *yz*-planes at the frequencies of 2.45 GHz and 5.5 GHz are depicted in Figs. 6 and 7. Apparently, this CDMCS provides a bidirectional pattern with different beam peak at the two bands. In addition, both simulated and measured radiation patterns of this proposed antenna are in the similar figure, and in good reasonably agreement.

a)



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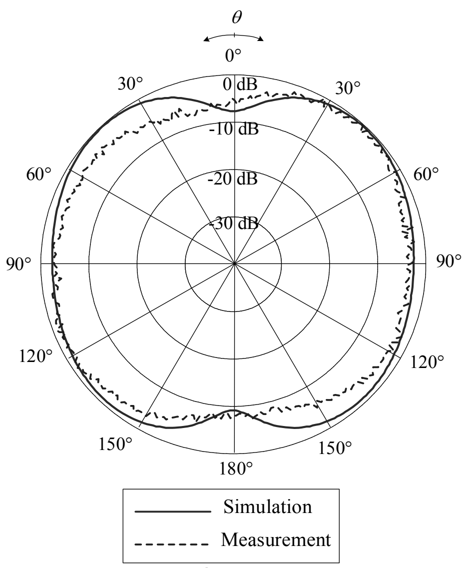

Fig.7. Radiation pattern at 5.5 GHz in: (a) *xz*-plane and (b) *yz* plane

Conclusions

The gain enhancement of dual-band antenna for 2.45/5.5 GHz WLAN applications is proposed by using a technique of DCTCs of PGP. Obvious that this antenna can entirely cover the required bandwidths ranging from 2.4-2.485 GHz and 5.15-5.825 GHz with decent radiation characteristics and magnitude of S_{11} lower than -10 dB. By modifying its partial ground plane, the antenna gains are improved with the radiation efficiency of 97.5% and 89.5% for the lower and upper bands, respectively. This presented antenna gives a bidirectional pattern with the maximum gains of 2.66 dBi for the lower band and 4.0 dBi for the upper band. Furthermore, antenna prototype was made and measured to verify the simulation results. Apparently, the measured results can confirm the simulation. With its ease structure and decent performance, this proposed CDMCS with MPGP is supposed to be a good candidate in dual-band system for WLAN applications.

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