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A Dual Band Non-Concentric Circular Rings Microstrip Antenna Design for Wi-Fi Application

Kareem Madhloom Gatea

Author affiliations:
Department of Electronics and Communication Engineering, Al-Nahrain University, Iraq

Email:
kareem.madhloom.1@nahrainuniv.edu.iq

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Abstract

In this paper we design a dual band patch antenna for Wi-Fi application it works in two different frequencies the first one in bandwidth of 480 MHz and impedance bandwidth of 18.75% (2.32. to 2.8 GHz) with resonant frequency 2.56 GHz this band can cover the Wi-Fi the second bandwidth is 4 GHZ and the impedance bandwidth 53.33% (5 GHz – 9 GHz). With resonant frequency 7.5 GHz, this band of frequency can cover the WLAN 5.8GHz, the 6GHz band it operates at frequency range (5.925 - 7.125 GHZ) it used for unlicensed Wi-Fi with bandwidth of 1.2 GHZ its application on Wi-Fi 7 and Wi-Fi 6E. Another application of the antenna in 8 GHz band it operates at the range (7.725 – 8.275 GHz). We use the CST package to design and simulated the propose antenna with dimensions of 35 mm×21 mm×1.6 mm.

Keywords: circular patch Microstrip Antennas, rings antenna, Wi-Fi, Dual-Band, WLAN, 6 GHz band, 8GHz band.

تصميم هوائي ثنائي النطاق ذو حلقات دائرية غير متحدة المركز لتطبيقات Wi-Fi

كريم مظلوم كاطع

الخلاصة:

في هذه الورقة البحثية قمنا بتصميم هوائي رقعة ثنائي النطاق لتطبيق Wi-Fi وباستخدام حلقتين دائريتين غير متحدة المركز يعمل بترددين مختلفين الأول بعرض نطاق ٤٨٠ ميجا هرتز وعرض نطاق معاوقة ١٨,٧٥٪ (٢,٣٢ إلى ٢,٨ جيجا هرتز) مع تردد رنين ٢,٥٦ جيجا هرتز يمكن لهذا النطاق تغطية Wi-Fi وعرض النطاق الثاني هو ٤ جيجا هرتز وعرض نطاق المعاوقة ٥٣,٣٣٪ (٥ جيجا هرتز - ٩ جيجا هرتز). مع تردد رنين ٧,٥ جيجا هرتز ، يمكن لهذا النطاق من التردد تغطية شبكة WLAN 5.8 جيجا هرتز ، ويعمل نطاق ٦ جيجا هرتز في نطاق التردد (٥,٩٢٥ - ٧,١٢٥ جيجا هرتز) ويستخدم لشبكة Wi-Fi غير المرخصة بعرض نطاق ١,٢ جيجا هرتز وتطبيقه على Wi-Fi 7 و .Wi-Fi 6Eتطبيق آخر للهوائي في نطاق ٨ جيجاهرتز يعمل في النطاق (٧,٧٢٥ – ٨,٢٧٥ جيجاهرتز). نستخدم حزمة CST لتصميم ومحاكاة الهوائي المقترح بأبعاد ٣٥ مم × ٢١ مم × ١,٦ مم.

1. Introduction

The wireless communication is one of promising research topic in the recent years. Antenna represent the backbone for any wireless communications system. Many paper has been written in this field but microstrip antenna always on demand because it has low cost, profile, and light weight, antenna has single resonant frequency. multiple frequency bands are needed for modern wireless communications system. A dual-band rectangular patch was design for wireless communication with defected ground plane to meet the requirement of 2.5GHz and 3.5GHz [1].A X-shaped patch designed to get dual and triple band frequencies using five rectangular slots to produce Ku and K bands its can be used for satellite communication [2]. For Wi-Fi frequency a wide bandwidth and high gain antenna proposed and simulated using CST studio suite [3]. A L-shaped antenna which coupled with ground parasitic resonator to produce a tri-bands for WLAN, WiMAX and Bluetooth application was proposed [4].

A four element dual-band MIMO antenna for LTE and 5G application to cover the frequency band (1550-2650 MHz) and (3350-3650 MHz) was introduce [5].

A dual band is achieved by adding a different slot shape to radiating patch with inverted V-shape and inverted C-shape to get (2.98-5.3GHz) and (6.6-7.2GHz) [6]. A tri band antenna that operates at 2.45, 3.5 and 5.8 GHz are designed using coplanar waveguide, the patch is loaded with inverted L-shaped stub to gate 2.4 GHz and other open end stubs was added to get the 3.5 and 5.8GHz [7].

Many recent research was introduce in last years that present a dual band antenna [12-15],a dual band crescent shaped introduce a two half circular patch HCP with defected ground plane[12], an enhanced gain dual band antenna was design at 3.5 GHz using three L –Shaped to enhance impedance match[13], Ahmad Salamin M, Zugari present a dual band small antenna its working frequency 3.6 and 5.8 GHz for wireless application [14], a semi-circular antenna and partial ground plane to get wide frequency for WiMax and Wi-Fi is presented[15]. In this paper we want to design antenna cover all Wi-Fi frequencies at 2.4 GHz,5.8 GHz, and 6Ghz bands.

The propose antenna is very easy to fabricated and has small size, also the antenna has large bandwidth impedance 480 MHz at the first band and 4 GHz in the second band that can increase the data traffic, so large data can be transfer per unit time.

The structure of paper is as follows, section 2 present the design of the proposed antenna, a parametric study is presented in section 3, the result and discussion is shown in section 4, and finally the conclusion is presented in section 5.

2. The Proposed Antenna Design

A single-band circular patch antenna was designed using the following equations 1 and 2 [8]

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\epsilon_r F}\left[ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \quad \ldots\ldots\ldots\ldots\ldots 1$$

$$\text{Where} \quad F = \frac{8.791\times10^9}{f_r\sqrt{\epsilon_r}} \quad \ldots\ldots\ldots 2$$

Where a is the radius of the patch, h the thickness of substrate, ϵ_r is relative permittivity of the substrate and f_r is the resonant frequency.

When we used the above equations to design circular patch at 2.4 GHz and choose FR-4 as a substrate with $\epsilon_r = 4.3$ and h=1.6 mm we get $a = 17.14\ mm$ and we choose the width and length of substrate 46mm the antenna named AntI is shown in Fig. 1 and its return loss is shown in Fig.2. Its feeding probe fed from underneath by coaxial line under the center of the circle by 7mm toward the - y axis. and we used fall ground plane.

Then the geometry of the AntI was modifying to ring microstrip antenna named as AntII with the same substrate type and thickness of AntI but with defected ground plane this modification led us to get the triple band with resonant frequency at 2 GHz, 5.9 GHz and 8.2GHz. fig. 3 show the AntII front and back view and the S11 show in fig. 4. Table 1 show the dimensions of AntII

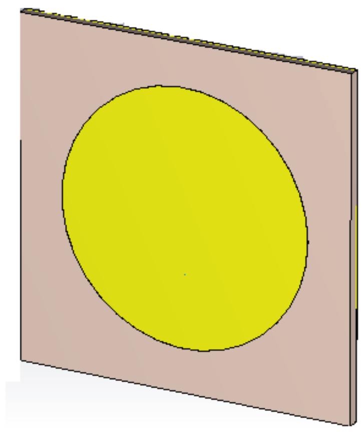


Figure (1): AntI the radius of antenna 17.14mm

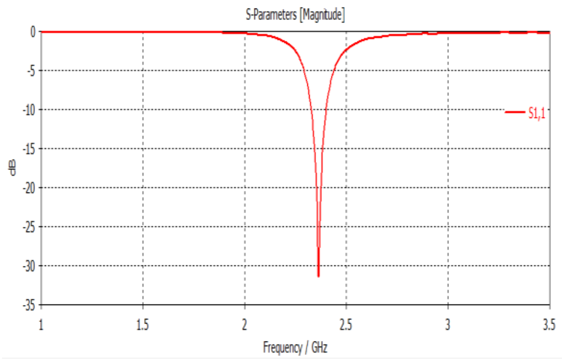


Figure (2): The return loss of AntI

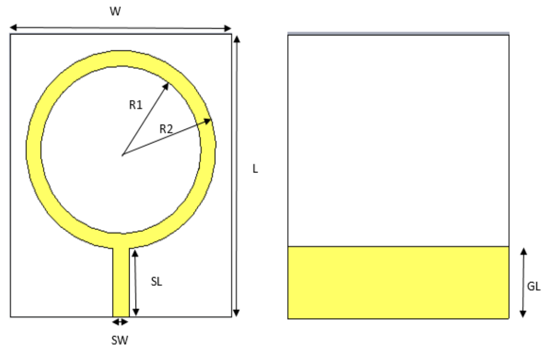


Figure (3): Front and back view of AntII

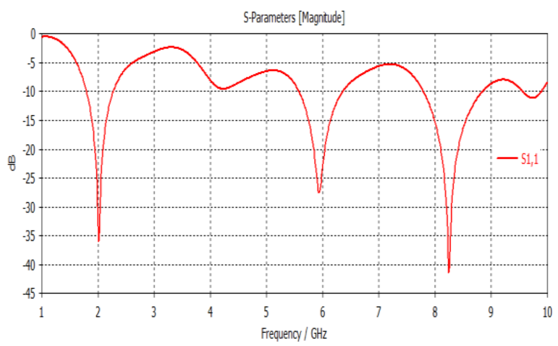


Figure (4): the return loss of AntII

Table (1): the optimize dimensions of Antenna AntII (in mm)

W	L	R1	R2	SL	SW	GL
40	49	15	17.2	11.86	2.9	12

The propose antenna printed on FR-4 substrate its thickness h=1.6 mm and $\epsilon_r = 4.3$. This material has excellent mechanical and electrical properties and it used widely for manufacturing printed circuits boards also it has stability in use and ease to fabrication. A microstrip line used to feed the patch with power to radiated it. The antenna has a compact structure with to WP×LP×h. the radiating patch is a two non-Concentric circular rings the propose antenna is shown in fig. 5 and the optimal parameter are listed in table 2.

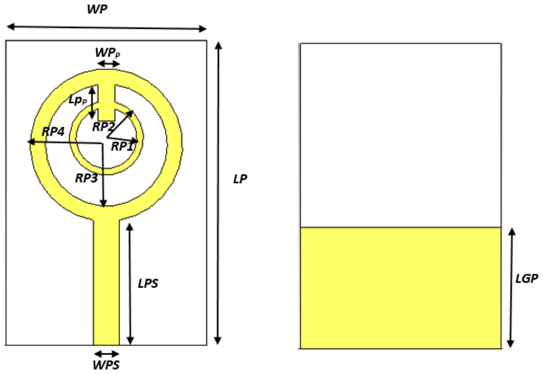


Figure (5): front and back view of AntIII

Table (2): The optimize dimensions of Antenna AntIII

Parameter	Value(mm)	Parameter	Value(mm)
WP	21	WPP	2
LP	35	LPP	4.22
RP1	3.5	LPS	14.62
RP2	4.25	WPS	2.9
RP3	7	LGP	14
RP4	8.75		

3.Parametric Study of Propose Antenna:

To see the effect, of each parameter a parametric study is important on some parameter of the antenna we choose two parameters RP4 it represents the radius of the external ring and RP2 its represent the radius of the internal ring to get an optimized antenna performance. Fig. 6 show the return loss different value of RP4 and constant of RP2 and fig.7 show the return loss of different value of RP2 and constant value of RP4.

It seen that the best S11 parameter optimum for our paper when RP4=8.75 mm and RP2=4.25 mm also we note that when the value of the radius of the external ring change its affect the starting of the second band and does not affect the ending of the second band but when the value of the radius of internal ring has change the its effect on the ending of the second band but does not affect the starting of the band. Also, the changing in the RP4 effect the resonant frequency of the first band but the changing in RP2 does not affect the resonant frequency of the first band.

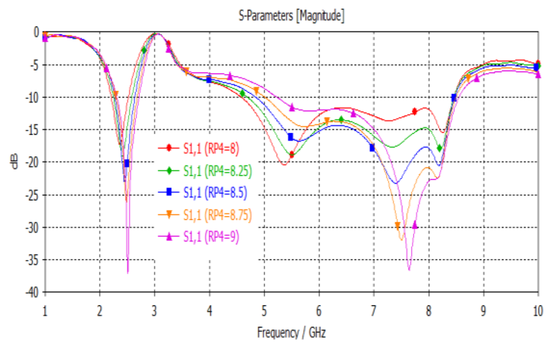


Figure (6): the return loss different value of RP4 and constant of RP2

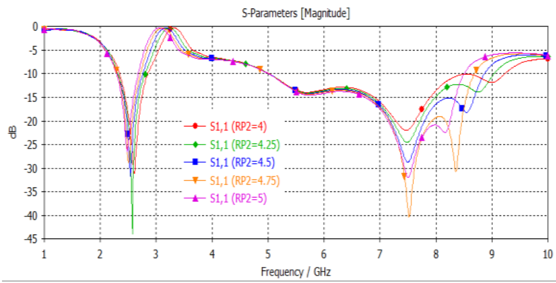


Figure (7): the return loss of different value of RP2 and constant value of RP4.

4.Results and Discussion:

The proposed antenna (AntIII) is optimized and investigated by CST microwave studio the return loss (S11) is shown in Fig.8 and the realized gain of the AntIII is shown in Fig. 9. From the fig. 8 we note that the operating frequency of the first band is 480 MHz (2.32. to 2.8 GHz) its suitable for Wi-Fi application with maximum return loss -45.6 dB and at the second band the operating frequency is 4GHz (5 to 9 GHz) with maximum return loss is -24.4 dB many applications are designed to work in this band of frequency the like WLAN because its clustered around 5.8GHz also the propose antenna cover the 6GHz band that FFC open it for unlicensed Wi-Fi use also the Wi-Fi 7 and Wi-Fi 6E are operating in the 6GHz band. The second band can cover the 8 GHz band which is use by high capacity and medium capacity and fixed point-to-point links.

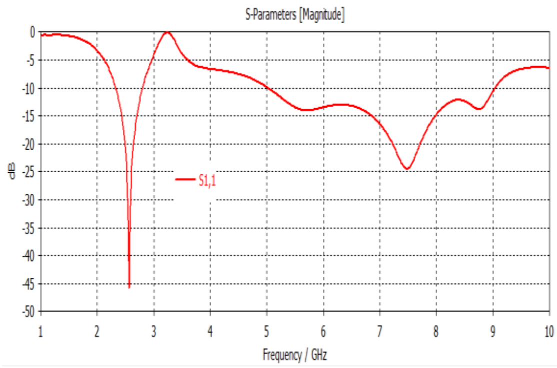


Figure (8): The return loss of AntIII

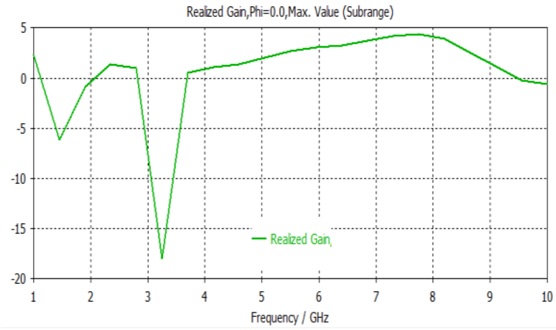
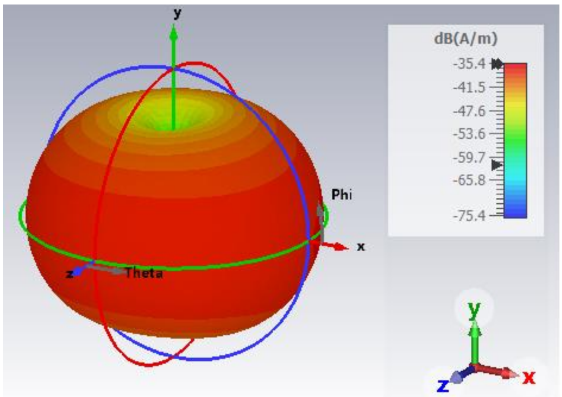


Figure (9): The realized gain of the AntIII

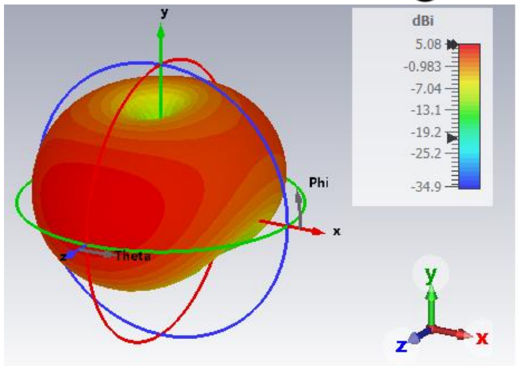
As shown in figure 9 the realized gain in first band is about 1.4 dB and for the second gain is 4.35 dB this gain makes the AntIII suitable to provide a good communication link for Wi-Fi application. Fig. 10a and b show the far field radiation pattern of the AntIII antenna for both band at resonant frequency, the figure shows the radiation pattern of AntIII is omnidirectional for the first band at 2.56 GHz and approximately omnidirectional for the second band at 7.5 GHz.

To observe the effect of the resonant frequencies the surface current of AntIII at 2.56 GHZ and at 7.5GHz are shown in fig. 11 and fig. 12. We note that the surface current in the 2.56 GHz is concentrate mainly in the strip line feeding and partially in the outer ring, but at the second resonant frequency 7.5 GHz the surface current is concentrate on the strip line feeding and mainly concentrate at the inner ring that indicate the two rings are used to generate the two resonant frequencies.

Table 3 show the result of comparison of the propose double rings antenna with related prior antenna. From this table we can see in comparison with [3] the antenna AntIII has better bandwidth in the second band but less in the first band. The return loss S11 of the antenna AntIII has good performance at both bands. [9] has small size than AntIII but the antenna AntIII has better bandwidth and return loss at both bands. With comparison with [10]and [11] the antenna AntIII has smaller size wider bandwidth and better return loss. From this comparison we can conclude the propose antenna has good performance than the other and its suitable all Wi-Fi application because its cover all frequency band reserved for Wi-Fi.



(a)



(b)

Figure (10): The far field radiation pattern (a) at 2.56 GHz (b) at 7.5 GHz

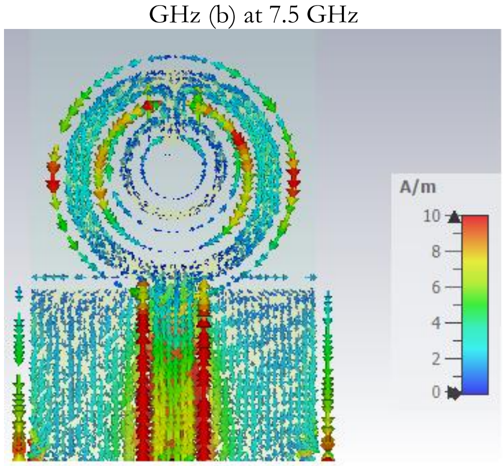


Figure (11): The surface current at 2.56 GHz

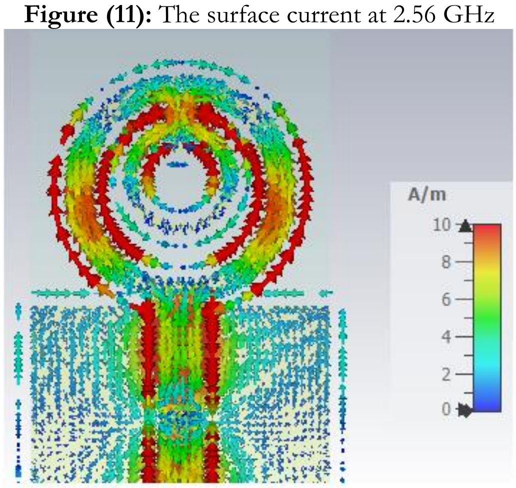


Figure (12): The surface current at 7.5 GHz

Table 3 The comparison of propose antenna with related work

Ref.	Dimensions (mm)	Operating Frequency (GHz)	S11 (min. value in dB)	Band-width (MHz)
[3]	10×50	2.4 5.8	-31.17 -42.05	600 1250
[9]	24×21	2.5 5.8	-29.9 -15.16	100 200
[10]	50×50	2.4 5	-17.6 -12.8	210 1010
[11]	39.4×32.9	2.4 5.8	Less -15 Less -30	72 715
Propose antenna	35×21	2.5 5	-45.6 -24.4	480 4000

5. Conclusions:

In this paper, two non-Concentric circular rings microstrip patch antenna is designed to operates in two frequency bands with enhanced bandwidth, at the first band the bandwidth is 480 MHz at resonant frequency 2.56 GHz and return loss -45.6 dB and 4 GHz in the second band at resonant frequency 7.5 GHz and return loss -24.4 dB, the characteristics of the propose antenna meet the requirement of the Wi-Fi application at the frequencies 2.4 GHz, 5.8 GHz, 6GHz band for unlicensed Wi-Fi and the 8 GHz band. The realized gain in first band is about 1.4 dB and for the second gain is 4.35 dB.

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