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Design of Circular Patch Antenna for Ultra-Wide band Application Using CST Software

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Abstract:

An antenna is a device that is used to convert guided electromagnetic waves EM waves. Significant developments have been done to design compact, minimal weight, low profile antennas. The technologist has focused on the design of microstrip patch antennas, resulting in various microstrip antennas. Microstrip antennas may be made of any geometrical shape and dimension. In this paper microstrip patch antenna has a radiating circular patch on one side of a dielectric substrate having very small thickness and has an infinite ground plane on the other side Dielectric materials may be considered as the backbone of microstrip antennas. Here we have designed the circular microstip patch antenna for Ultra-Wide Band applications, which covers the band 3.1 to 10.6 GHz. The antenna is designed using two substrates RogerRT5880 and RogerRT5870 and a microstrip line feed is used. Design of the antenna is carried out using CST Microsoft Studio simulation Software. So, that we get the directivity 3.326dBi (Roger RT5880), and 3.638 dBi (Roger RT5870).

Keywords: Circular patchantenna, Ultra-Wide Band, Roger RT5880 and Roge rRT5870 substrate, CST.

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تصميم هوائي شريطي دائري لتطبيقات النطاق العريض للغاية باستخدام برنامج CST

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الملخص:

الهوائي هو جهاز يستخدم لتحويل الموجات الكهرومغناطيسية الموجهة إلى موجات EM. وقد تم إجراء تطورات كبيرة لتصميم هوائيات مدمجة وخفيفة الوزن ومنخفضة الارتفاع. ركز خبراء التكنولوجيا على تصميم هوائيات الرقعة الشريطية الدقيقة، مما أدى إلى ظهور العديد من هوائيات الرقعة الشريطية الدقيقة. يمكن تصنيع هوائيات الرقعة الشريطية الدقيقة من أي شكل هندسي وبُعد. في هذه الورقة، يحتوي هوائي الرقعة الشريطية الدقيقة على رقعة دائرية مشعة على جانب واحد من ركيزة عازلة ذات سمك صغير جدًا ولها مستوى أرضي لا نهائي على الجانب الآخر. يمكن اعتبار المواد العازلة بمثابة العمود الفقري لهوائيات الرقعة الشريطية الدقيقة. لقد صممنا هنا هوائي الرقعة الشريطية الدقيقة الدائري لتطبيقات النطاق العريض للغاية الذي يغطي النطاق من 3.1 إلى 10.6 جيجاهرتز. تم تصميم الهوائي باستخدام ركيزتين RogerRT5880 و RogerRT5870 ويتم استخدام تغذية خطية للشريط الدقيق. تم تصميم الهوائي باستخدام برنامج محاكاة CST Microsoft Studio. وبذلك نحصل على اتجاهية dBi (Roger 3.326 (RT5880)، و3.638 dBi (Roger RT5870).

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الكلمات المفتاحية: هوائي رقعة دائري، نطاق واسع للغاية، ركيزة RogerRT5880 وRogerRT5870، CST.

Introduction:

The antenna functions as a transducer by transforming electric currents into EM waves during signal transmission and back into electric currents during signal reception. In the world of wireless communications, antennas are extremely important. Parabolic reflector, patch, slot, and folding dipole antennas are a few examples of antenna types. Every antenna prescribed, although the various table text styles are provided. The formatter will need to create these components; incorporating the applicable criteria that follow type has useful characteristics and applications. Today's antennas come in hundreds of various varieties. Circular microstrip patch antenna consists of circular shape radiating element on one side of the substrate having the ground plane on other side. Feeding can be done by using any one of the methods such as co-axial feed, line feed, inset feed, proximity coupling or aperture coupling shown in figure 1.

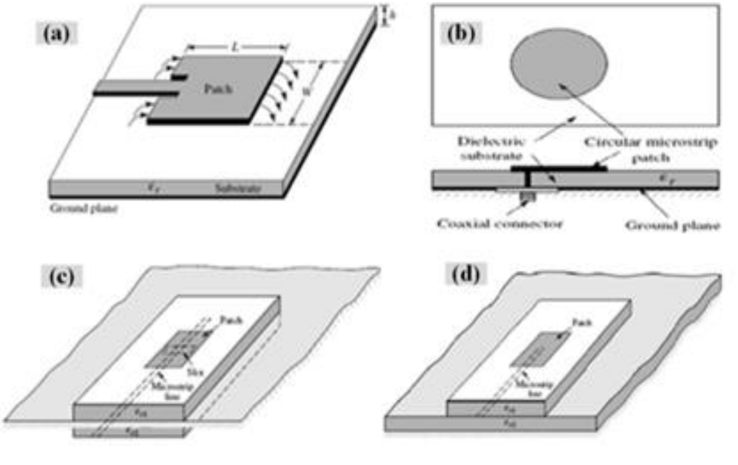

Figure.1Patchantennafeed:(a)Microstriplinefeed,(b)coaxialprobefeed,(c) Aperture-couplingfeed and (d) Proximitycoupling feed [2].

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One of the most popular feeding techniques used for designing the UWB antennas is the microstrip feed line. Circular microstrip patch antenna has been designed using substrates Rogers RT/duroid5880 (εr= 2.2, h=0.79 mm), Rogers RT/duroid5870 (εr= 2.33, h=1.6 mm) [1].

The methodology is in four main stages:

1. Study on architecture & design equations for circular microstrip patch antenna.
2. Dimensions of Circular microstrip patch antenna to be calculated for different substrate.
3. Simulation of Circular antenna for different substrates by using CST software.
4. Analysis and tabulation of results obtained and comparing VSWR, S11, and radiation pattern with each other.

The rest of the paper is organized as followsSection III is the proposed methodology, which includes introduces designing the circular microstip patch antenna for Ultra-Wide Band Section IV describes the experimental results; Section V conclusion the paper.

Literature review

Ali and Ahmed [3] studied on designed operating at microwave frequencies at the ISM band implemented on a simplified model for both normal and abnormal breast tissue for detecting the presence of a tumor in stage I, by comparing each of the return loss, gain, and directivity, also six casesof the tumor location were studied to reveal the location of its presence. SAR value wascalculated over 10 g of tissue. All simulations and Results were carried out using CST microwave studio.

Mukta et al [4] presented the design of a compact circular microstrip patch antenna for WLAN applications which covers the band 5.15 to 5.825 GHz. The antenna is designed using1.4 mm thick FR-4 (lossy) substrate with relative permittivity 4.4 and amicro strip line feed is used. The radius of the circular patch is chosen as 7.62mm. Various performance parameters like return loss, bandwidth, VSWR, gain, directivity, total efficiency and radiation pattern are studied. The proposed antenna resonates at the frequency of 5.5GHzwith a wider bandwidth of 702MHz (from 5.129 GHz to

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5.8309 GHz) as expected. The antenna provides low return loss of -31.58 dB, good gain of 3.23 dB and directivity of 4.28dBi and high total efficiency of around 79% at 5.5 GHz. These parametric results indicatethat the proposed compact designed circular microstrip patch 14 antenna attains good performance and is suitable for WLAN applications.

Tasnim [5] Studied on a comparative performance study on circular and elliptical shape microstrip patch antennas and their arrays using different feeding techniques at an X band. The resonant frequency is chosen at 10 GHz which has a variety of application in wireless communication. CST Microwave Studio is used for design and simulation. It is found that microstrip line feeding shown better performance than coaxial probe feeding considering gain and directivity A 3558.12 mm2 antenna having 2x4 array of circular patch with linefeed that gives 16.2 dB gain, 16.4 dB directivity with 94.42% efficiency and 1.54 of VSWR are results of the proposed model. It is found that microstrip line feeding shown better performance than coaxial probe feeding considering gain and directivity.

The proposed methodology microstrip circular patch antenna:-
The proposed microstrip circular patch antenna is designed using CST Studio Suite 2019 software. Once the design is complete, the antenna simulated in the software to estimate its real world performance. For antenna design, it is assumed that the dielectric constant of the substrate (εr), the resonant frequency(5.6GHz), and the height of the substrate h (in mm) are known. Then a set of simplified equations of cavity model is used for calculating design parameters of circular microstrip patch antenna as follow:
1-Calculate the radius of circular patch:
The patch is in the form of circle, where the radius of the radiating elements can be obtained through the equation (1):

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

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Where:
a =Circular radius dimension (mm).
h = Thick of substrate (m).
F = logarithmic function (F) of radiating element.
ε_r = Relative dielectric permittivity of substrate (F/m).

Equation (1) does not take into consideration the fringing effect. Since fringing makes the patch electrically larger, the effective radius of patch is used:

$$F = \frac{8.791 \times 10^9}{fr\sqrt{\varepsilon r}} \tag{2}$$

Where:
f_r = resonant frequency (MHz)

2-Calculate the Effective radius of circular patch:

$$a_e = \left\{1 + \frac{2h}{\pi \varepsilon r F}\left[ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{\frac{1}{2}} \tag{3}$$

Where:
a_e = Effective radius (mm)

2- Calculate the width of ground plane:

$$W = \frac{v_0}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}} \tag{4}$$

Where:
$W = width\ of\ grouend\ plane\ (mm)$
v_0 = Free space velocity of light

3- Calculate the length of ground plane:

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$$L = L_{eff} - 2\Delta L \tag{5}$$

Where:

L_{eff} = Estimating the Effective Length

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}} \tag{6}$$

$\varepsilon_{eff} = Effective\ substrate$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}[1 + 12\frac{h}{w}]^{-\frac{1}{2}} \tag{7}$$

ΔL = extension of the length (mm)

$$\Delta L = 0.412h\frac{\left(\varepsilon_{r_{eff}} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{r_{eff}} + 0.3\right)\left(\frac{W}{h} + 0.8\right)} \tag{8}$$

Simulation Results:

The simulation results of circular patch antenna using CST Studio Suite 2019 Software are shown from.figure2 to5. The CST software used to simulate the antenna design can display several antenna parameters such as return loss (S11), VSWR, gain, directivity, radiation pattern, and efficiency. To analyze and evaluate the antenna performance of the proposed antenna design using these antenna parameters, the summary of the results of the simulated antenna designs for designed circular patch antenna are presented and discussed below.

- **Return Loss (S11):**

Return loss is an important parameter that measures the effective power delivery of the designed antenna [5]. Figure 2(a, b) below

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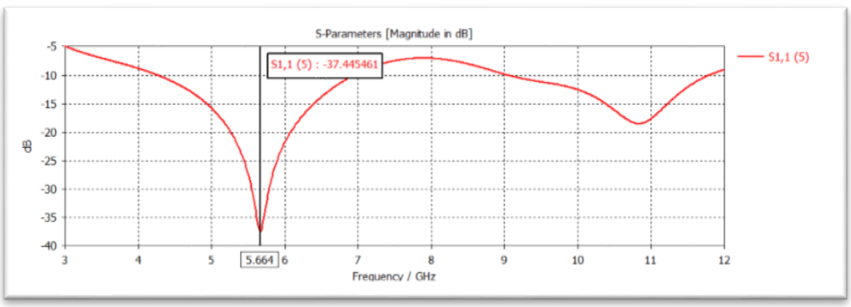
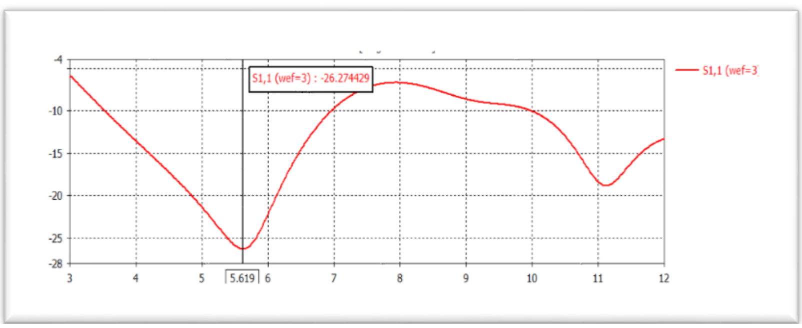
plots the return loss or reflection response (S11) of the designed circular patch antenna. From figure (a, b) 2, it is evident that the designed circular patch antenna is resonating at the operating frequency of 5.6 GHz, with a measured return loss of-37.4dB for (RT5880) and-26.27dBfor (RT5870).



(a)



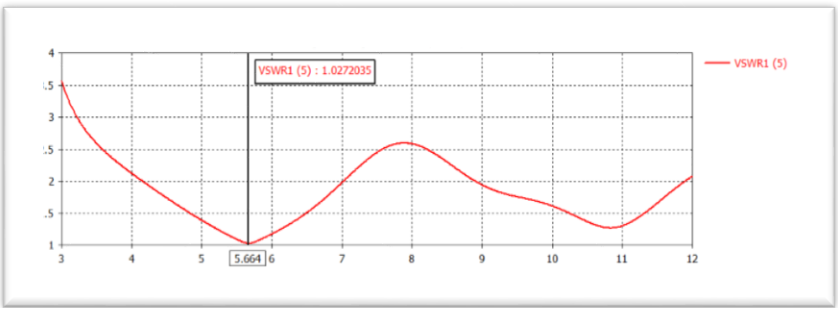
(b)

Figure 2 a: Return Loss vs. frequency plot of designed circular patch antenna (RT5880).
b: Return Loss vs. frequency plot of designed circular patch antenna (RT5870).

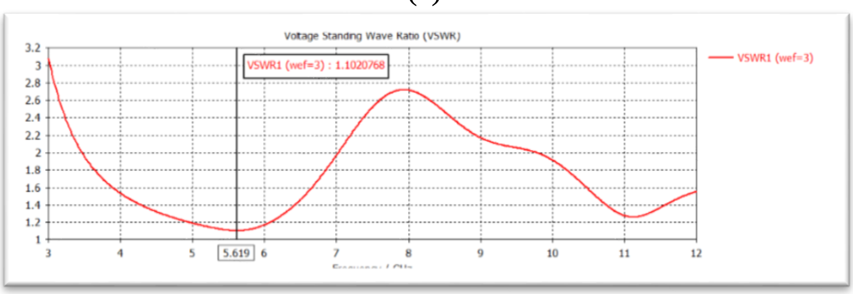
- Voltage Standing Wave Ratio (VSWR)

Voltage standing wave ratio (VSWR) is a way to measure transmission line imperfections [7]. The desirable VSWR range of 1<VSWR< 2 is desired for a good antenna operation of any designed antenna [8]. From figure 3(a,b) below, the designed circular patch antenna achieved a VSWR of 1.02 for (RT5880) and

1.1 for (RT5870) at the resonant frequency of 5.6 GHz. The VSWR values of 1.02, 1.1 indicates a good impedance matching, as it is slightly below the maximum acceptable value of 2 for a well matched antenna.



(a)



(b)

Figure 3.a: VSWR versus frequency plot of proposed circular patch antenna (RT5880).
b: VSWR versus frequency plot of proposed circular patch antenna (RT5870).

- Gain and Directivity

The gain of an antenna is the measure of the antenna efficiency. It describes how far signals can travel through space, while the directivity of an antenna measures the ability of the antenna to radiate energy in a particular direction [2]. The higher the gain, the farther signals will travel [8]. The 3D polar plot of the simulated antenna design is shown in figure 4 (a,b) below.

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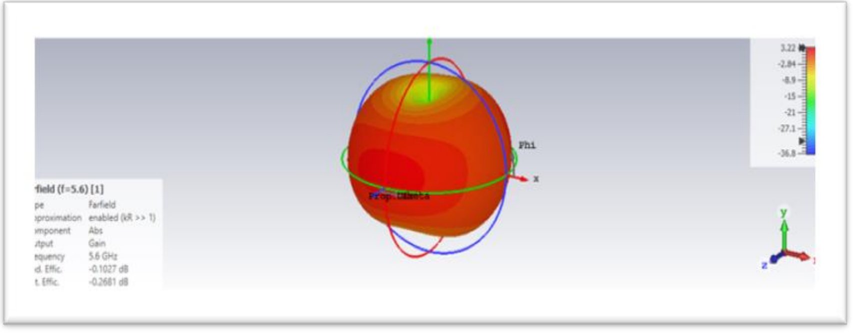
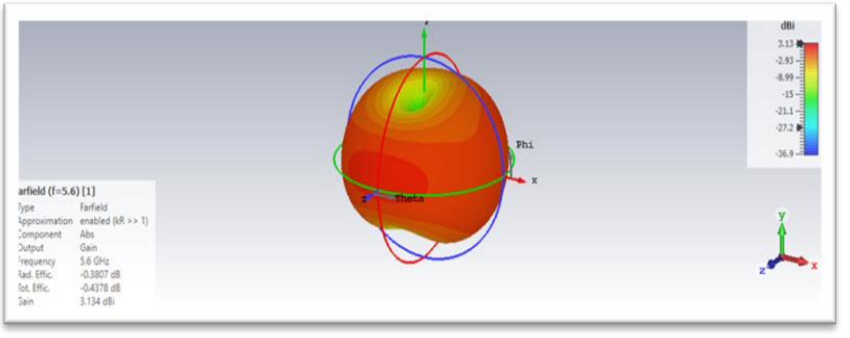


(a)



(b)

Figure 4. a: 3D Gain plot of simulated circular patch antenna (RT5880).
b: 3D Gain plot of simulated circular patch antenna (RT5870).

From the 3D polar plot shown in figure 4(a,b) , the gain of the designed are circular patch antenna 3.24 dBi for (RT5880)and 3.214 dBi for (RT5870), at the resonant frequency of 5.6 GHz.

- **Radiation Pattern:**

The radiation pattern of an antenna describes the shape and direction of the beam of electromagnetic wave from the antenna. The measured far-field radiation patterns of designed circular patch antennas are shown in figure. 5(a,b,C,d) below. The radiation pattern shown in figure.5(a,b) shown the E-plane (phi=0 deg, x-z plane) and figure 5(c,d) H-plane (phi=90 deg, y-z plane) radiation pattern of the designed circular patch antenna in polar plot. The

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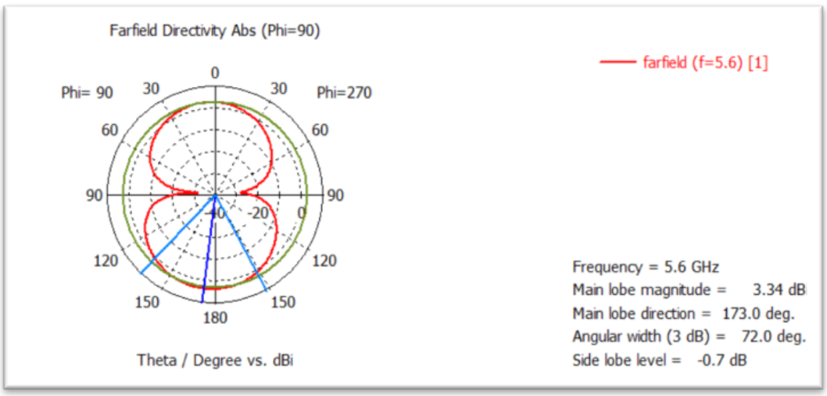
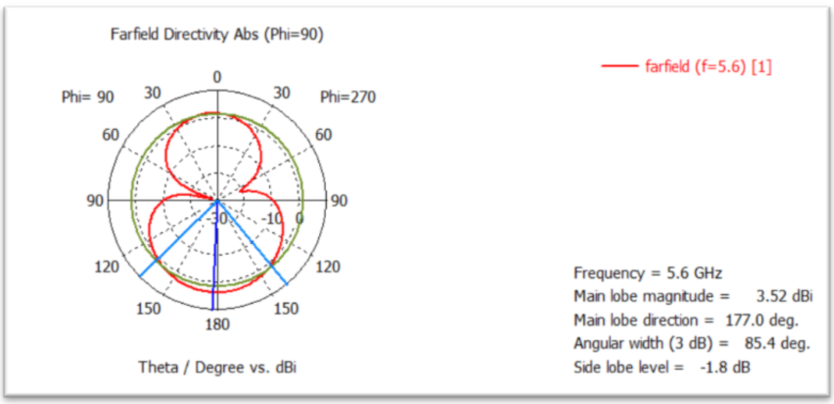
radiation pattern of the proposed antenna is omnidirectional with minimum side lobe.

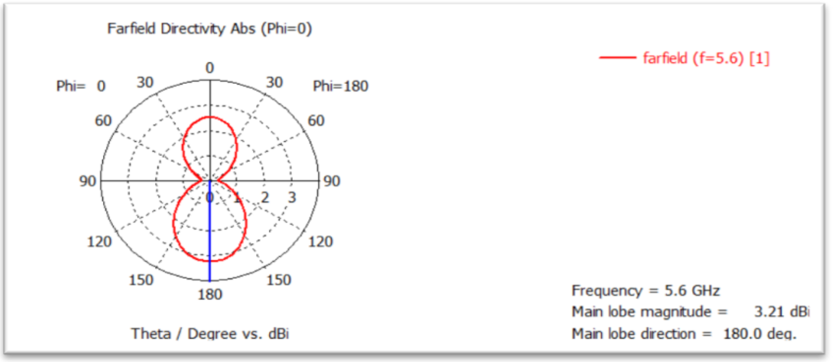


(a)

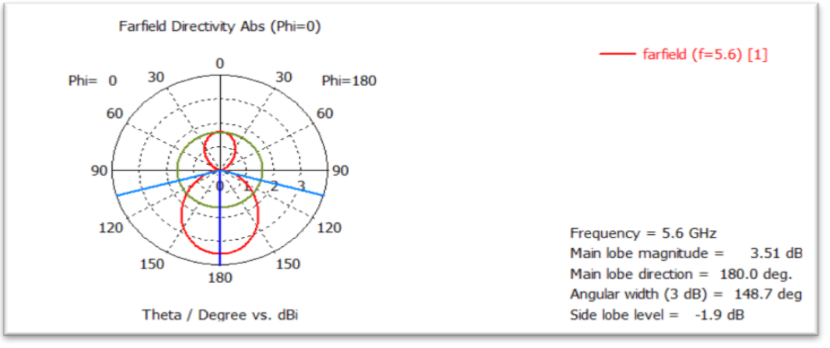


(b)

Figure 5. a : Radiation pattern of designed circular patch antenna (RT5880) in (E-plan).
b : Radiation pattern of designed circular patch antenna (RT5870) in (E-plan).



(c)



(d)

Figure 5: c : Radiation pattern of designed circular patch antenna (RT5880) in (H-plan).
d : Radiation pattern of designed circular patch antenna (RT5870) in (H-plane).

- **Antenna Efficiency**:
The antenna efficiency of the designed circular patch antenna A in this research work is an important parameter that expresses the ratio of the total power radiated to the net power received by the antenna. In this research work, the radiation efficiency of the designed circular patch antenna is 96%for (RT5880) and 88% for (RT5870). This high antenna efficiency of 96%, 88% achieved by the proposed circular patch antenna is therefore good for practical purposes as it

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is slightly above the 80-90% efficiency noted by for most micro strip patch antennas [8].

Summary of simulation results and analysis:

The summary of the simulation results of the designed circular patch antenna in this research work is shown in table 1. This table presents the performance parameters of the designed circular patch using the basic antenna parameters characteristics such as resonant frequency, return loss (S11), VSWR, Gain, Directivity, and Efficiency.

Table 1: Summary of simulated results of circular patch antenna

Materials	RT5880	RT5870
ε_r	2.2	2.33
Frequency(GHZ)	5.6	5.6
S11(db)	-37.4	-26.27
VSWR	1.02	1.10
Directivity (dBi)	3.326	3.638
Gain (dBi)	3.224	3.214
Efficiency.%	96%	88%

Table 2 shows the parameters performance of the proposed design compared with some other works.

Table 2 the performance parameters for our designed and other works.

Parameters	Our design	Reference [3]	Reference [4]	Reference [5]
S11(dB)	-37.4	-57.75	-31.576	
Gain (dBi)	3.224	8.17	3.229	16.2
Directivity(dBi)	3.326	4.97	4.275	16.4

Conclusion:

The aim of this paper was to simulation circular patch antenna for Ultra Wide Band by using CST software at center frequency (5.6GHz) for two substrates Roger RT5880 and Roger RT5870. The result was as following, the S11-37.4, VSWR 1.02, and Directivity 3.326 dBi for Roger RT5880and S11 - 26.27, VSWR 1.10, Directivity 3.638 dBi for Roger RT5870. It is found that Roger

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RT5880 shown better performance than Roger RT5870 considering return loss and efficiency.

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