Design of Optical Gold Printed Antenna in Terahertz Band for ON Body WBAN Applications

Bouchra Moulfi, Souheyla Ferouani, Ziani Kerarti Djalal

Abstract – **This paper presents a design and analysis of a gold nano patch circular antenna in Terahertz band for ON body WBAN applications using CST software. This antenna is simulated with Silicon substrate ($\varepsilon_r = 11.9$) and have dimensions of 63.72*83.46 µm^2 for width and length respectively, the radius of patch is taken 16µm. To analyze and compare the effect of material substrates on the proposed nano patch antenna, another types of substrates as Alumina ($\varepsilon_r = 9.9$), Rogers R04003C ($\varepsilon_r = 3.5$), RT Duriod 5880 ($\varepsilon_r = 2.2$), and RT Duriod 3210 ($\varepsilon_r = 10.8$) are used. To confirm our results, we have compared the simulation results with the paper [1] and the references cited in his work; the return loss obtained is –54.96 dB, the gain is 5.40 dB with 7.574 of directivity. The simulation results are very satisfying and the proposed antenna can be used for WBAN applications.**

Keywords – **WBAN, Printed antenna, Terahertz transmission, Optical transmission, Return loss S_{11}, Radiation pattern.**

I. INTRODUCTION

To improve the life and psychology of patients who must remain under medical supervision [2], a new wireless body network radio frequency technology called WBAN has been used (Fig. 1). A small sensor or actuator is integrated in or on the human body or even on clothing. The latter can measure blood pressure, temperature, oxygen, ECG, EEG, blood sugar, energy level, nerve signals etc [3] and then send it to a base station monitored by doctors in a database [4]. There are three types of using printed antennas in WBANs: IN-Body: the antenna is inserted into the human body or implanted under the tissue, ON-Body: the antenna is placed on the body and communicates with another wearable antenna, OFF-Body: the antenna communicates with a medical base station or another device [5]. The WBAN antenna can also be used for sports applications when an athlete is training alone or away from his coach like swimming [6], also it can be used for the evaluation of the mental and physical brain activity of racing drivers [7], etc. The WBAN antenna is a low power consumption antenna [8] and fulfills three requirements: a low radiation in the rear direction so that it does not affect the internal organs of the body, a compact size and a low height for easy integration and finally a combined effect between antenna and body.

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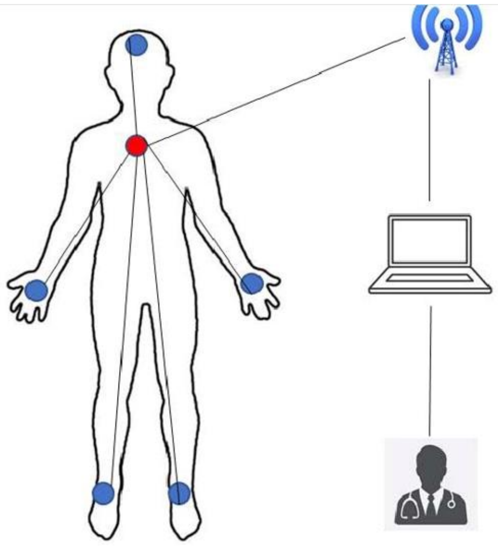


Fig. 1. WBAN applications on humman body

With these requirements, the design of a WBAN antenna will be too complicated and to solve this problem, researchers have thought of designing patch antennas with reflectors for an Omni directional radiation pattern [9]. The terahertz band above the microwave frequencies which is from [0.1ï 10] THz is the most used in the recent years, several researches have been done in this frequency spectrum like: Lens based antennas [10-11], antenna based on new materials [12-15] and yagi-Uda and dipole optical antennas [16]. The purpose of choosing this spectrum is the increase of the transmission rate, the widening of the bandwidth and also the minimization of the transmission time (real time communication).

In this work, we designed a Nano circular patch antenna for Terahertz transmission from [0.1ï 10] THz, especially for ON Body WBAN applications using Gold as material of patch with 3.205 µm of thickness and silicon substrate with permittivity $ύ_r = 11.9$ and 5.4 µm of thikness. This work has been compared with [1] in which he used RT Duriod $ύ_r = 10.8$ and Silicon $ύ_r = 11.9$ as substrates with 10µm of thikness. Its simulation results are presented with ANSYS HFSS software. The proposed antenna gives better results with Silicon substrate, the results are given by using CST microwave. The return loss obtained is –54.96 dB with 305.91 GHz of bandwidth and 5.40 dB of gain which is very suitable for medical application in optical transmission.

Other types of substrates have been used by keeping the same shape of the proposed antenna to evaluate the performance of the Nano-antenna in optical transmission.

II. Circular Patch Antenna Design

We designed a circular nano patch antenna that operates in Terahertz transmission and designated for ON body WBAN applications. It is consisting of a gold patch with 3.205 of thickness and a Silicon substrate ($\varepsilon_r = 11.9$, $h = 5.4$ µm). The antenna is fed by a microstrip line of impedance 50 Ω as shown in Fig. 2. The parameters of the antenna are calculated with the following equations [17]:

$$F = \frac{8.791\cdot 10^{9}}{f_r\cdot 10^{12}\cdot \varepsilon_r^{0.5}}\cdot 10^{4}, \tag{1}$$

$$a = \frac{F}{\left(1+\left(\frac{2\cdot h\cdot 10^{-4}}{\pi\cdot\varepsilon_r\cdot F}\right)\cdot \ln\left(\left(\frac{\pi\cdot F}{2\cdot h\cdot 10^{-4}}\right)+1.7726\right)^{0.5}\right)}, \tag{2}$$

$$ae = a\cdot\left(1+\left(2\cdot\frac{h}{\pi\cdot a\cdot\varepsilon_r}\right)\cdot\ln\left(\frac{\pi\cdot a}{2\cdot h}\right)+1.7726\right)^{0.5}, \tag{3}$$

$$L_g = ll + 2\cdot ae + 6\cdot h, \tag{4}$$

$$W_g = 2\cdot ae + 6\cdot h, \tag{5}$$

where h represents height of the antenna, a radius of the antenna and ε_r the dielectric constant of the substrate used. L_g and W_g are the length and width of the substrate.

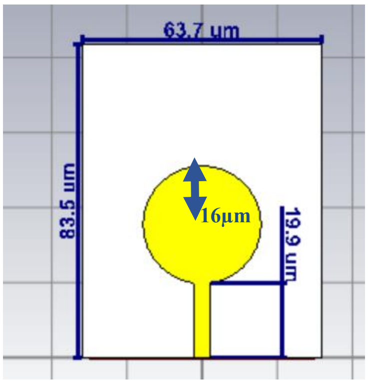


Fig. 2. Proposed nano circular patch antenna

III. Simulations and Results

A. Simulation Result with Silicon Substrate

Fig. 3 shows the simulation results of the proposed antenna with Silicon substrate ($\varepsilon_r = 11.9$).

As we can see in Fig. 6, the radiation from the back lobes is very low, so we can say that the proposed antenna is very suitable to use in Terahertz transmission especially on human body for WBAN applications.

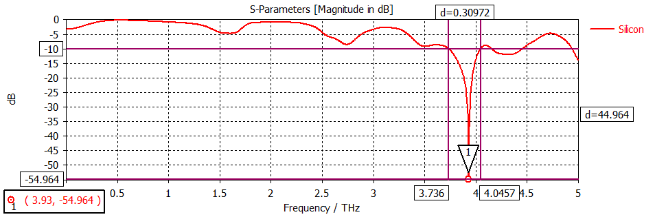


Fig. 3. Reflection coefficient parameter S_{11} of the proposed antenna with Silicon substrate

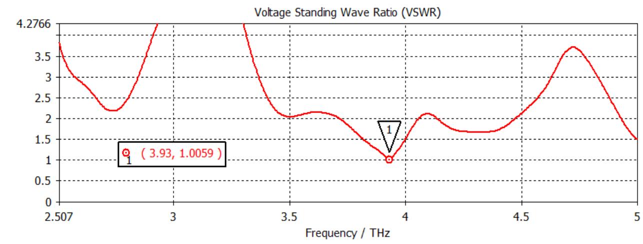


Fig. 4. VSWR of the proposed antenna

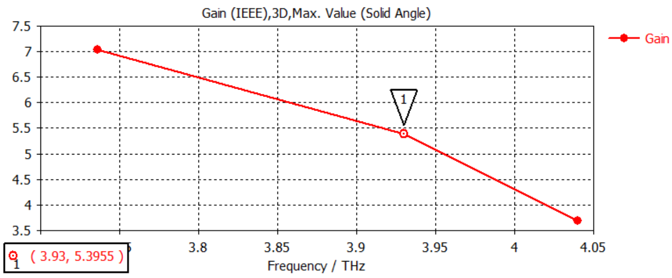
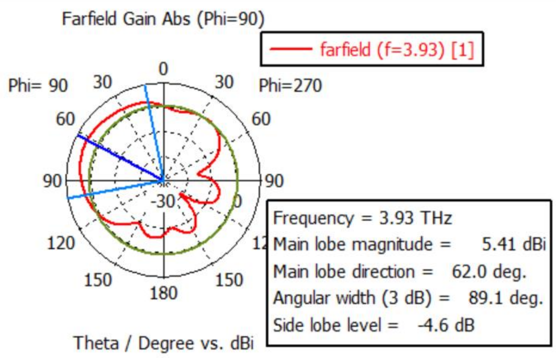
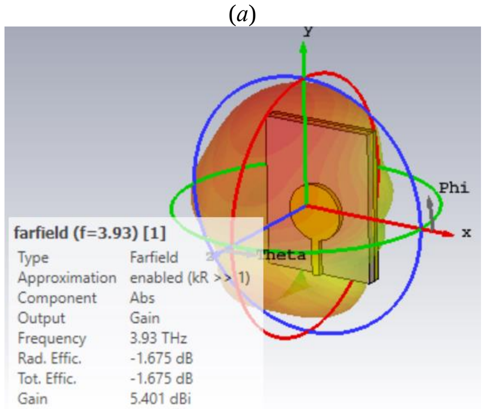


Fig. 5. Gain of proposed antenna with Silicon substrate



(a)



(b)

Fig. 6. Radiation pattern of the proposed antenna: (a) polar radiation pattern, and (b) 3D radiation pattern

B. Simulation Result with others Substrates

Others type of substrates are used, by keeping the same shape of the proposed gold patch antenna, such as Alumina (Ụ̊ = 9.9), Rogers R04003C (Ụ̊ = 3.5), RT Duriod 5880 (Ụ̊ = 2.2), and RT Duriod 3210 (Ụ̊ = 10.8) for analyzing the antenna effects. Fig. 7 shows the antenna design for each one of them and Figs. 8-12 present the simulation results obtained.

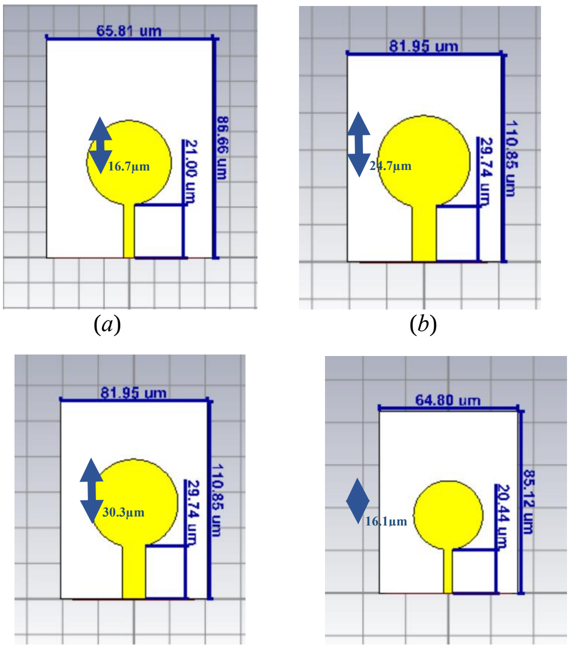


Fig. 7. Nano circular patch antenna design for each substrate: (a) Alumina, (b) RogersRO4003C, (c) RT Duriod 5850, and (d) RT Duriod 3210

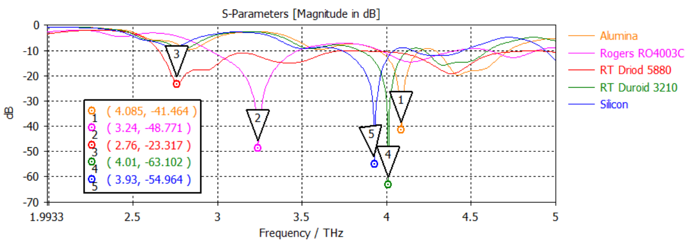


Fig. 8. Reflection coefficient parameter S11 for each substrate substrates

As we can have seen in Fig. 8, several frequencies are obtained by changing the material substrate such as 4.085 THz, 3.24 THz, 2.76 THz, 4.01 THz and 3.93 THz with the use of Alumina, Rogers 4003C, RT Duriod 5880, RT Duriod 5880 and Silicon respectively. The return loss obtained for each one of them is: –41.464 dB, –48.771 dB, –23.317 dB, –63.102 dB and –54.964 dB respectively.

As shown in Fig. 9, the VSWR in all frequencies obtained with different substrates is less than 2.

As shown in Fig. 10, the gain obtained for 4.085 THz, 3.24 THz, 2.76 THz, 4.01 THz and 3.93 THz frequencies is 5.25 dB with alumina, 4.36 dB with Rogers 4003C, 4.49 dB with RT Duroid 5880, 5.038 dB with RT Duroid 3210 and 5.3955 dB with Silicon respectively.

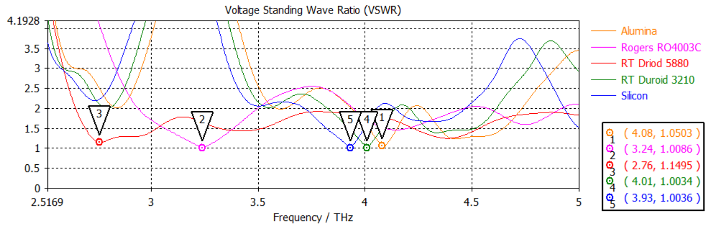


Fig. 9. VSWR of the proposed antenna

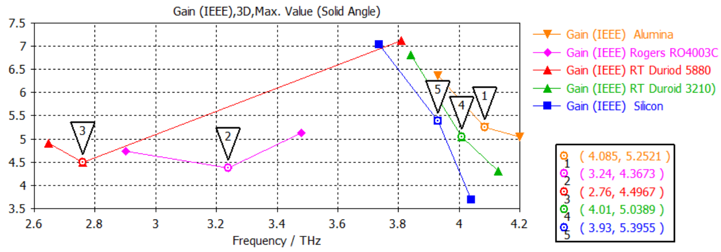


Fig. 10. Gain obtained for all the substrates

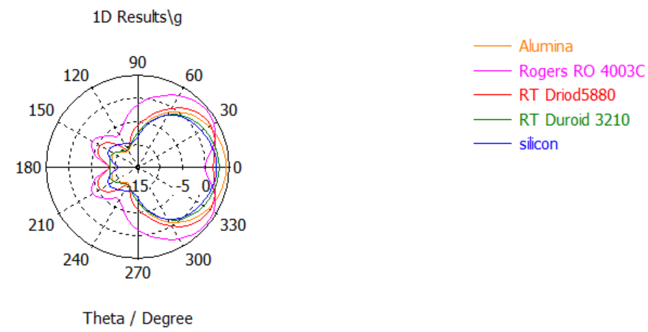


Fig. 11. Polar radiation pattern of the antenna for each substrate

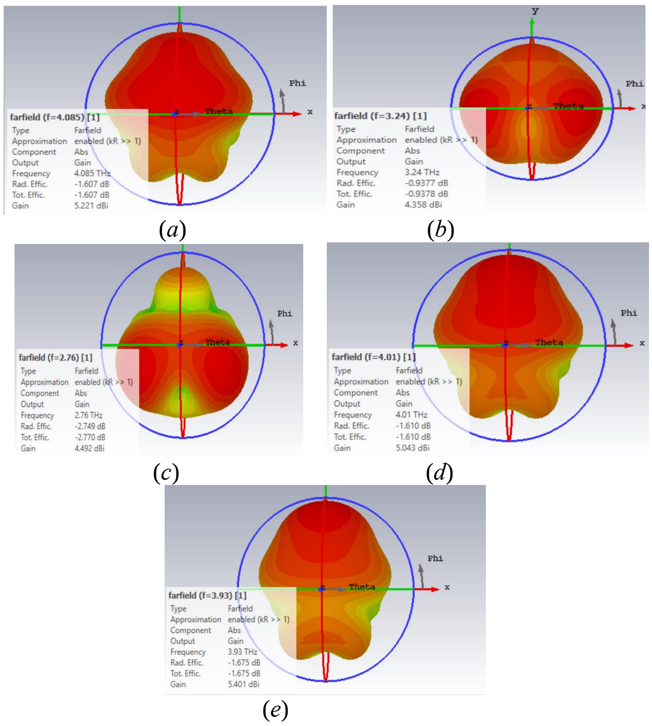


Fig. 12. 3D radiation pattern of the antenna: (a) Alumina substrate, (b) Roger 3004C substrate, (c) Roger 5880 substrate, (d) RT Duriod 3210 substrate, and (e) Silicon substrate

TABLE 1

COMPARISON OF RESULTS WITH OTHER REFERENCE

Antenna parameters	Proposed antenna		[1]	
Substrates	Silicon (ε_r=11.9)	RT Duroid 3210 (ε_r=10.8)	RT Duroid 6010 (ε_r=10.2)	Silicon (ε_r=11.9)
a [μm]	15.66	16.198	40	/
f_r [THz]	3.93	4.01	2.270	3.254
S_{11} [dB]	-54.96	-63.10	-22.39	-42.67
Gain [dB]	5.40	5.06	4.8	5.3
Directivity	7.574	6.637	3	3.1
B_p [GHz]	305.91	280.59	/	/

TABLE 2

COMPARISON OF RESULTS WITH OTHER SUBSTRATES

Antenna parameters	Proposed antenna				
Substrates	Silicon (ε_r=11.9)	RT Duroid 3210 (ε_r=10.8)	Roger 4003C (ε_r=3.55)	Alumina (ε_r=9.9)	Roger 5880 (ε_r=2.2)
a [μm]	15.66	16.198	24.77	16.7	30.36
f_r [THz]	3.93	4.01	3.24	4.085	2.76
S_{11} [dB]	−54.96	−63.10	−48.77	−41.32	−23.317
Gain [dB]	5.40	5.06	4.346	5.25	4.504
Directivity	7.574	6.637	5.294	6.719	7.229
B_p [GHz]	305.91	280.59	559.07	280.59	1166.7

As we can see in Figs. 11 and 12, the radiation from the back lobes is very low with the chosen substrates.

As it can be seen in Table 1, the proposed nano patch antenna gives better performance than [1]. The size of the proposed antenna is less than [1] with a return loss of −54.96 dB and gain of 5.40 for Silicon substrate and −63.10 dB and gain of 5.06 with RT duriod wich is very satisfying for optical transmission.

Table 2 resumes all results obtained with each substrate, we obtained several frequencies in terahertz band from [0.1–10] THz by changing the material substrate. The results obtained are very satisfying in terms of reflexion coefficient, gain and bandwidth.

IV. CONCLUSION

In this work, a nano circular patch antenna operating at terahertz frequency from [0.1–10] THz is designed for WBAN applications. The use of Silicon substrate material (ε_r = 11.9, h = 5.4 μm) and gold patch antenna with 3.2 μm of thickness is very suitable for on body medical application. The size of antenna is very compact, the back lobe radiation is minimum which is very satisfactory, it doesn't affect the human body. The proposed antenna is very suitable for use on the human body.

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