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A Wearable Flexible antenna integrated on a Smart Watch for 5G Applications

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A Wearable Flexible antenna integrated on a Smart Watch for 5G Applications

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Abstract. This paper presents a design of dual-band flexible wearable antenna for modern 5G applications to integrate on a smartwatch. This antenna is a rectangular antenna which the patch and the ground etched on new flexible material is called "ULTRALAM® 3850HT". This material is characterized by thin flexible cores with low and stable dielectric constant, which is a key requirement for high frequency and wearable designs. The dielectric constant ε_r is equal to 3.14, and loss tangent tanδ is equal 0.005 of the ULTRALAM® 3850HT flexible material. The presented antenna is designed to operate at 38 GHz and 60 GHz. The SAR (specific absorption ratio) is also introduced and SAR results will be shown. The presented antenna with and without the smartwatch are simulated using HFSS and CST 2018.

1. Introduction

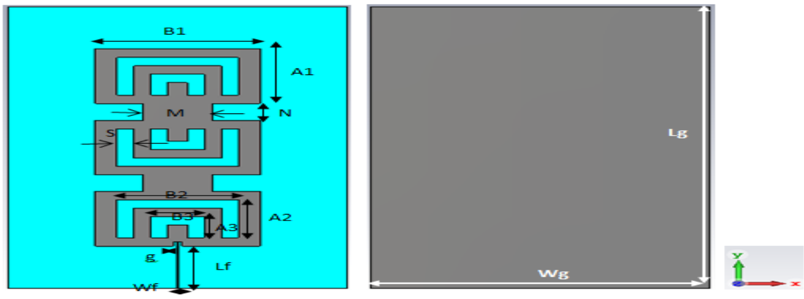
There are many problems that wireless communications in 4G such as frequency resources for their customers are not enough [1]. Therefore, the millimeter wave technology offers a new model of wireless communication in various fields including mobile devices, automobiles, military, medical and many more [2]. The mm-wave frequencies are the most suitable for broadband requirements in telecommunication systems that provide a frequency range in millimeter (20-300 GHz). Of these ranges, select four resonance frequencies of 26, 28, 38 and 60 GHz, where the antenna is required at these frequencies to use the current 5G spectrum simultaneously [3]. The main advantage of millimeter wave technology is to reduce the volume of the devices because they have very high resonance frequencies and thus the smaller size of the antenna; also, high speed and high capacity [4]. There are also two bands of 5G technology other than the millimeter frequency band, the "5G low band" and the "5G average band" that use frequencies from 600 MHz to 6 GHz, especially 3.5-4.2

GHz [5]. But this paper interests only by the frequency band of millimeter wave technology for fifth-generation applications. On the other hand, when any antenna attached or closed to the human body is called wearable antenna. The wearable antenna or antenna worn by the body radiates electromagnetic waves that are absorbed by human body tissues [6]. The absorption of these waves will cause damage and burn human tissues. It is, therefore, necessary to reduce the interaction of electromagnetic energy towards human body tissues from wearable antennas when used. Electromagnetic wave absorption is measured from human tissue at a specific absorption rate [7]. Besides, the SAR limit is based on the Standardization Committee and is varied in different regions around the world. In the United States regulated by the Federal Communications Commission (FCC), where the maximum acceptable value of SAR 1.6 W / kg, with an average of more than 1 gram of tissue [8]. However; in Europe, the maximum acceptable SAR 2.0 W / kg as averaged over 10 grams of tissue organized by the International Commission on Non-Ionizing Radiation Protection (ICNIPR) [8].

In this paper, the dual-band flexible wearable fifth-generation mm-wave antenna is designed and simulated to integrate it into a simulated smartwatch. The antenna design is a rectangular antenna included six U-slots on the patch. The patch and the ground plane etched on new flexible material as a substrate is called “ULTRALAM® 3850HT”. This antenna is designed to operate at two resonance frequencies 38 GHz and 60 GHz. The presented antenna is a body-worn antenna where it’s integrated into the smartwatch. So, the SAR (specific absorption ratio) value should be calculated for the presented design. Furthermore, the antenna and the smartwatch are simulated using two different techniques. These are HFSSTM from Ansoft which used FEM and CST STUDIO SUITETM 2018 which used FIT. The two software packages are different; therefore the second has been used to confirm the results determined using the first. Also, good agreement is obtained between these results.

2. Antenna Design

Figure 1 shows the simulated geometry of the proposed dual-band rectangular millimeter-wave antenna. This proposed antenna includes six U-slots loaded on the top of the patch specially designed to achieve the dual-band concept with good impedance matching. The patch and the ground plane are rectangular and etched on the opposite sides of new flexible material is called "ULTRALAM® 3850HT" as a substrate with very thin thickness h = 0.05 mm to achieve the flexibility for the wearable antenna, relative permittivity ε_r = 3.14 and tan (δ) = 0.005. Also, this material is characterized by low and stable dielectric constant. The optimized dimensions are tabulated in Table 1.



(a) (b)

Figure 1. The geometry of Proposed Rectangular Wearable Antenna: (a) Top and (b) Back view.

Table 1. The Proposed Antenna Dimensions

Wg	Lg	A1	B1	A2	B2	A3	B3	M	N	S	g	Wf	Lf
20	33.5	6.5	9.7	4.5	7.12	2.5	3.12	4.1	2	1	0.2	0.1	10

3. Results and Discussion

The simulation analysis of the presented antenna is carried out by applying differently two commercial software packages are called HFSS from Ansoft and CST 2018 to confirm the results. The simulation of the return loss S11 for the proposed rectangular wearable antenna is shown in Figure 2. From the results obtained, this presented antenna is operated at two resonance frequencies 38GHz and 60 GHz at the same time for 5G Applications. Also, there is a little shift between two results due to the two software packages are different where the HFSSTM from Ansoft used FEM and CST STUDIO SUITETM 2018 used FIT. The simulation results are mentioned in Table 2. Furthermore, the radiation pattern of the presented antenna in both planes: E-plane and H-plane are shown in Figure 3.

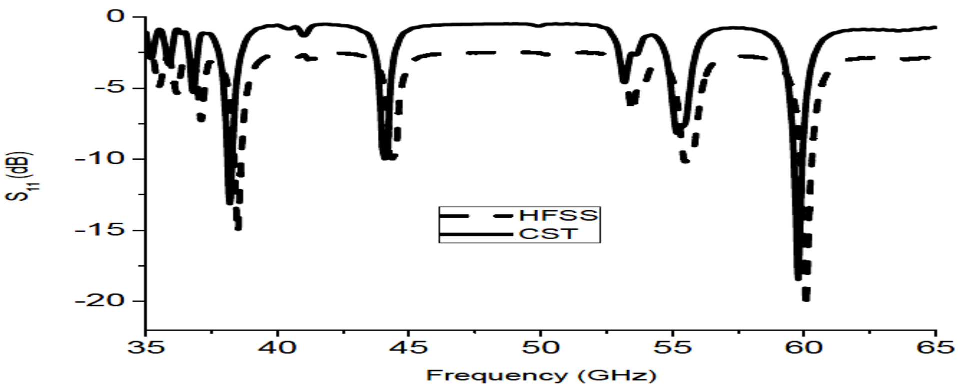
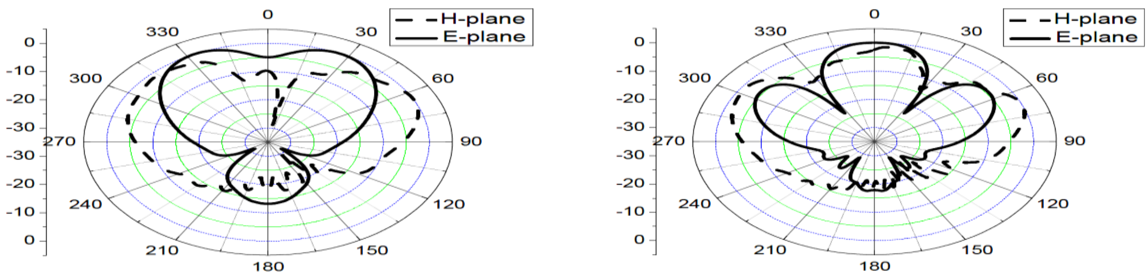


Figure 2. The Return Loss against Frequency for the Proposed Antenna.

Table 2. Simulation Results of the Proposed Antenna for 5G Applications

Frequency Bands (GHz)	Return Loss S11 (dB)	Gain (dB)	Total Efficiency (%)
37.949-38.391	-13.996	2.19	69.2
59.497-60.154	-19.268	4.43	73.7



(a) (b)

Figure 3. Radiation Pattern for Proposed Antenna in E-plane, H-plane at (a) 38, (b) 60 GHz.

4. Smart Watch Design

Nowadays, the field of smart wearable devices like smartwatches is growing rapidly and has attracted great attentions from publications and industries [9]. Generally, the wearable smartwatch antennas represent many challenges for a design engineer. It should be lightweight, flexible, small size, low profile and cost and also easy to integrate or carry by the human hand [10]. In this chapter, a smartwatch is designed, simulated and attached with a millimeter-wave antenna to operate on 5G wireless technologies. Figure 4 illustrates the geometry of the watch with a practical size. This watch consists of two parts: the watch body and rubber straps. The dimensions and materials properties of the watch are tabulated in Table 3.

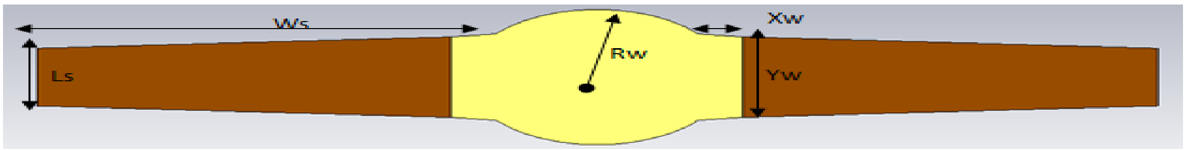
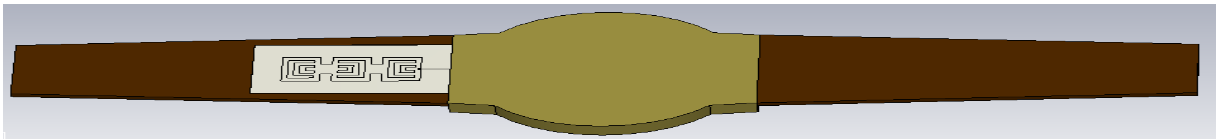


Figure 4. The Geometry of Smart Watch

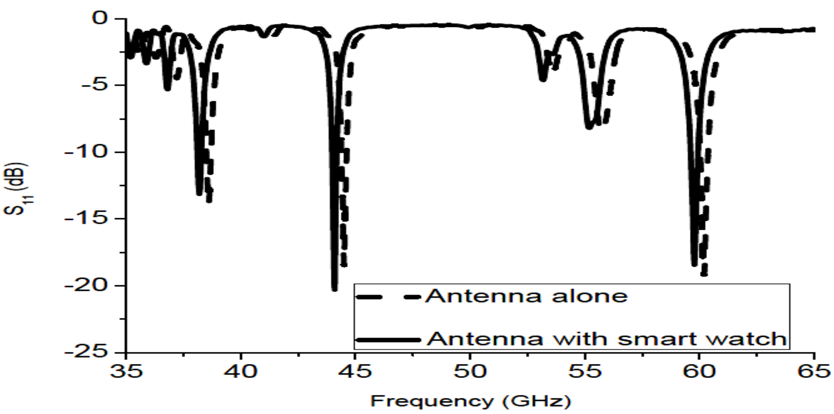
Table 3. The Dimensions and the Materials Properties of the Watch

Watch			Smart Watch			Strap				
Material: Alumina			Dimensions (mm)			Material: Rubber			Dimensions (mm)	
Thick.	Dielectric Constant	Loss Tangent	Rw	Xw	Yw	Thick.	Dielectric Constant	Loss Tangent	Ws	Ls
6	9.4	0.0004	23.5	7.96	28	1.9	3	0.0025	74	20

Next, the presented antenna above is integrated onto the designed watch to be smart. The antenna is placed near the main PCB board to obtain the required input power from the internal battery of the watch. The smartwatch with the proposed rectangular millimeter-wave antenna is shown in Figure 5a and the simulated return loss for the first proposed rectangular antenna with and without smartwatch is plotted in Figure 5b. From these results, there is a little shift in the return loss with the frequency; this is due to the presence of the smartwatch.



(a)

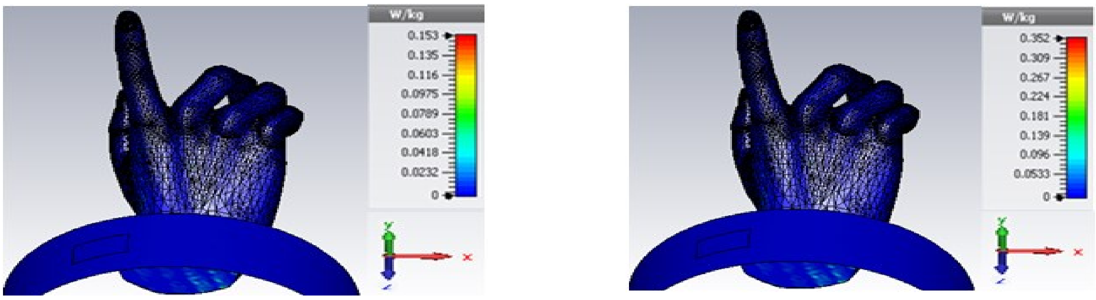


(b)

Figure 5. Smartwatch with proposed antenna: (a) Geometry and (b) S11 against frequency.

5. SAR Calculations

It is important to make sure that the humans are exposed to less electromagnetic waves and the presented smartwatch is safe. For these reasons, the specific absorption ratio (SAR) is studied, which must be satisfied the international safety standards, FCC (SAR<1.6W/kg over 1g) and ICNIRP (SAR<2W/kg over 10g). Figure 6 illustrates the simulated SAR distribution for the smartwatch with the proposed millimeter-wave antenna and attached to the human hand model at two resonances frequencies 38, and 60 GHz. These results are mentioned in Table 4. From these results, notes that all the SAR values results do not exceed unity.



(a) (b)

Figure 6. SAR on human hand model with the smartwatch at (a) 38 GHz, and (b) 60 GHz.

Table 4. Maximum SAR values by FCC (1g) and ICNIPR (10g) standards.

Frequency (GHz)	10 g	1g
38	0.153	0.326
60	0.352	0.631

6. Conclusion

In this paper, a flexible wearable dual-band antenna is analyzed and simulated for integration onto a simulated watch to make it smart for modern wireless 5G networks. This wearable antenna combines the hardness and flexibility in that one which is made of a material called “ULTRALAM® 3850HT”. This material is characterized by thin flexible cores with low and stable dielectric constant. This antenna is designed to operate at two resonance frequencies 38 GHz and 60 GHz. In this paper, the SAR value is very low, thus this smartwatch operated properly in the nearness of the human body. The presented antenna with the simulated smartwatch is simulated using HFSS and CST STUDIO SUITE 2018.

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