Chapter 4
A Dual-Band Flexible Wearable Antenna Integrated on a Smart Watch for 5G Applications

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ABSTRACT

This chapter focuses on the design of dual band flexible wearable antennas for modern 5G applications to integrate on a smartwatch. The first is a rectangular antenna which the patch and the ground etched on new flexible material is called ULTRALAM® 3850HT. This antenna is designed to operate at 38 GHz and 60 GHz. The second is a planar inverted-2F wearable antenna pasted on a jeans textile material. Two methods for measuring the dielectric properties of the jeans will be presented. This antenna is designed to operate at 28 GHz and 38 GHz. The SAR (specific absorption ratio) is also introduced and SAR results will be shown. Moreover, the proposed smartwatch under the bent condition will be also studied. These antennas are simulated using HFSS and CST 2018.

INTRODUCTION

Millimeter-wave technology brings a new model of wireless communication in various fields including mobile devices, automobiles, military, medical, IoT (Internet objects) and many more (Jajere, 2017). There are many problems faced in wireless communications in 4G such as the frequency resources for their customers are not enough (Huang, 2018). So, the millimeter wave frequencies are the most suitable solutions for the broadband requirement in communication systems which have the availability of millimeter frequency range (20 – 300 GHz) (Jun, Miao & Hui, 2017). From this ranges chosen four frequencies are 26, 28, 38 and 60 GHz where the operation of the antenna in these frequencies is requested to use the currently 5G spectrums in single systems (Imran, Farooqi, Khattak, Ullah, Khan, Khattak,

DOI: 10.4018/978-1-7998-1152-7.ch004

& Dar, 2018). The main feature of the millimeter wave technology is reducing the size of the hardware devices as they have very high resonant frequencies, therefore, the smaller size of the antenna, in addition, high speed and high capacity (Hong, Baek, & Seungtae, 2017). Also, there are two bands for 5G technology other than the millimeter-wave frequency band, they are "Low-band 5G" and "Mid-band 5G" using frequencies from 600 MHz to 6 GHz, especially 3.5 - 4.2 GHz (Parchin, 2016). This chapter focuses only on the frequency band of millimeter-wave technology for 5G applications.

Generally, when an antenna attached or closed to the human body is called wearable antenna. A wearable antenna or body-worn antenna radiates the electromagnetic waves (EMWs) which are absorbed by tissues of the human body. The absorption of these waves will cause damage and burn human tissues (Sunohara, Laakso, Hirata & Onishi, 2014). So, it is necessary to decrease the electromagnetic energy interaction towards the human body tissues from the wearable antennas when in use. The absorption of the electromagnetic waves (EMWs) from the human tissue is measured by the specific absorption rate (SAR) (Hirata, Fujiwara, Nagaoka & Watanabe, 2010). Further, the SAR safety limit is based on the standardization committee and is various in different regions over the world. In the US is regulated by the Federal Communications Commission (FCC) where the acceptable maximum SAR value 1.6 W/kg, averaged over 1 gram of tissue. But in Europe, the acceptable maximum SAR value is 2.0 W/kg averaged over 10 grams of tissue which is regulated by the International Commission on Non–Ionizing Radiation Protection (ICNIRP) (Zhao, Zhang, Chiu, Ying, & He, 2014).

In this chapter, dual-band flexible wearable 5G (Fifth-Generation) millimeter-wave antennas are designed and simulated for integration on smartwatch applications. There are two different designs are included in this chapter: the first design is a rectangular antenna including six U-slots on the patch. The patch and the ground plane are etched on new flexible material as a substrate which 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. This flexible material has a dielectric constant ε_r is equal to 3.14, and loss tangent tanδ is equal to 0.005. This antenna is designed to operate at two resonant frequencies 38 GHz and 60 GHz. The second antenna is a planar inverted-2F wearable antenna pasted on jeans textile material as a substrate. Two methods for measuring the dielectric constant (ε_r) and loss tangent (tanδ) of the Jeans material will be presented in this chapter: a microstrip ring resonator method and DAK equipment. This antenna is designed and simulated to operate at two resonant frequencies 28 GHz and 38 GHz.

The presented antennas are body-worn antennas where they are integrated into the smartwatch. Therefore, the specific absorption ratio (SAR) plays a vital role in the design of any body-worn antenna. So, the SAR value should be calculated for all the presented designs in this chapter. Also, in general, it's not possible to keep the smartwatch position in a flat at all the time. Therefore, the performance characteristic of the presented smartwatch with the two millimeter-wave antennas under the bent condition is also investigated. Furthermore, these antennas are simulated using two basically different techniques. These are HFSSTM from Ansoft which used FEM and CST STUDIO SUITETM 2018 which used FIT. The two software packages are basically different; therefore, the second has been used to confirm the results determined using the first.

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