Conformal Integrated Multi-Layer Thin-Film Antenna by Novel LITA Technologies for Smartwatch Wearable Device Applications

Wei-Yu Li1, Wei Chung1, Fu-Ren Hsiao2, Tune-Hune Kao3 and Meng-Chi Huang3
1ICL, ITRI, Hsinchu 31040, Taiwan
2Wireless Communications BU, ACON, New Taipei City, Taiwan
3MSL, ITRI, Hsinchu 31040, Taiwan

***Abstract* – This article presents a conformal integrated multi-layer thin-film antenna design implemented by novel LITA (Laser-Induced Integrated Thin-Film Antenna) technologies for smartwatch device applications. Through the proposed LITA technology which is jointly developed by ITRI and ACON in Taiwan, metal layouts of antennas can be formed on the internal surface of a smartwatch casing successfully with conformal, thin-film type, multi-layer and highly integrating characteristics. It is demonstrated that by designing a compact two-layer thin-film feeding capacitor by LITA, a much smaller PIFA antenna size (5×10 mm^2 only) can be achieved successfully compared to the PIFA with a co-planar capacitive feeding structure and the prior PIFA with a direct feed. The constructed antenna prototype analyzed with presence of a user's right hand is discussed in this paper.**

***Index Terms* — Compact antennas, Thin-film antennas, Smartwatch antennas, User's hand effect.**

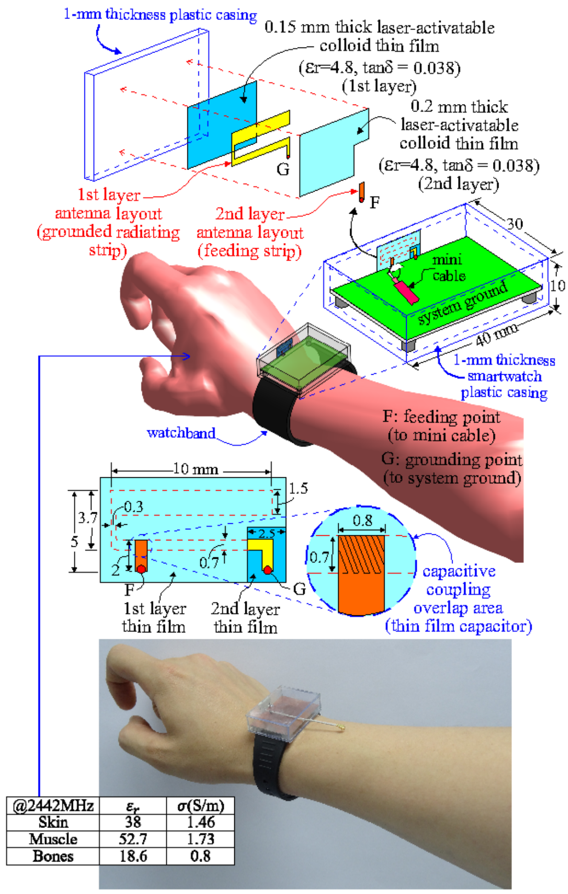
1. Introduction

Wearable smartwatch devices have become more and more popular nowadays. They can synchronize information with smart phones or tablet PCs via Wi-Fi or Bluetooth technology [1, 2]. One of main challenges for achieving these applications is to design antennas being small and concealed within the wearable devices. Some related prior papers have been published by introducing metal-frame type 2.4 GHz loop antennas [1] or PCB type Bluetooth PIFA antennas [2]. Besides, FPCB (Flexible Printed Circuit Board) and LDS (Laser Direct Structuring) processes are possible solutions for common practices [1, 3]. In this paper, a novel multi-layer thin-film antenna by LITA (Laser-Induced Integrated Thin-Film Antenna) technologies is proposed for achieving much smaller smartwatch antenna sizes successfully compared to the prior published literatures [1, 2].

The LITA technology is jointly developed by ITRI and ACON in Taiwan. LITA sprays a special laser-activatable colloid on surface of supporter materials to replace prior metal-particle-mixed plastics of LDS [3, 4] for achieving more flexibility on substrate choosing. Through the LITA, the metal layouts of antennas can be formed on internal surface of a device casing successfully with a thin-film type, conformal and highly integrating characteristics. The LITA technologies evolved from the LIM (Laser Induced Metallization) technology of ITRI [3] and enhance the insulativity of LIM colloid to improve the layer-by-layer fabrication characteristics. With this advantage of LITA, thin-film and multi-layer capacitor can be directly formed into antennas for achieving compact antenna sizes. The constructed smartwatch antenna prototype is analyzed with presence of a user's right hand and discussed in this paper.

2. Antenna Design

Fig. 1 shows the geometry of the proposed multi-layer thin-film smartwatch antenna by LITA technologies. The antenna is designed for 2.4 GHz Bluetooth operation (2400-2484 MHz). It is adhered on the internal surface of a 1 mm



@2442MHz	ε_r	σ(S/m)
Skin	38	1.46
Muscle	52.7	1.73
Bones	18.6	0.8

Fig. 1. Geometry of the proposed multi-layer thin-film smartwatch antenna by LITA technologies.

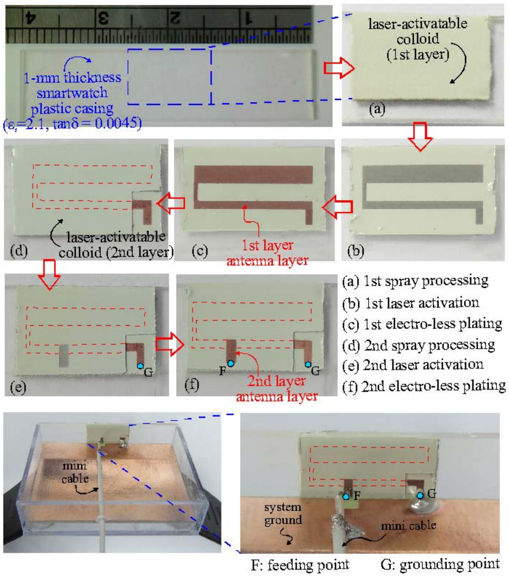


Fig. 2. Manufacturing process of the smartwatch antenna prototype implemented by the LITA technologies.

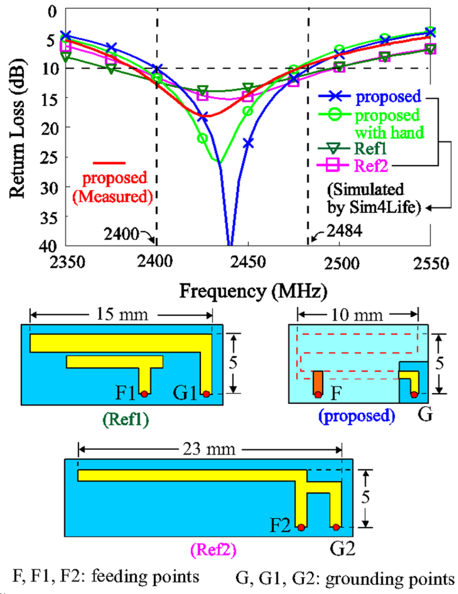


Fig. 3. Simulated and measured return loss analysis for the proposed and reference smartwatch antenna designs.

smartwatch plastic casing with a compact overall antenna size of 50 mm^2 (5×10 mm^2) only. The proposed antenna is a coupled-fed PIFA architecture with a capacitive coupling portion for generating 1/8 wavelength resonant mode [3] to reduce required antenna size compared to the traditional 1/4 wavelength PIFAs [2]. It is important to notice that by the multi-layer manufacturing process of LITA, the capacitive coupling portion can be formed to become a two-layer thin-film capacitor needing just a very small coupling overlap area (0.8×0.7 mm^2 only) due to the small thickness (0.2 mm) of the 2nd layer insulated colloid thin film as shown in Fig.1. The required layout area of the capacitive coupling portion becomes much smaller than the prior co-planar capacitive structure [3]. And because of this, the overall antenna size can be further reduced compared to the prior 1/4 and 1/8 wavelength PIFAs [2, 3]. Fig.2 shows the step-by-step manufacturing process of the proposed antenna by LITA. More details will be presented in the conference.

3. Result and Discussion

Fig.3 shows simulated and measured return loss analysis of the proposed antenna, the reference PIFA with one-layer co-planar coupling feed (Ref1), the reference traditional PIFA with direct feed (Ref2) and the proposed antenna with a user's hand model. From the results, good impedance matching (better than 10 dB) can be achieved for the four different antenna cases in the desired 2400-2484 MHz to cove 2.4 GHz Bluetooth operation. The simulated results and the simulation hand model are provided by SPEAG software Sim4Life [5]. With the capacitive coupling feeds, both the proposed antenna and Ref1 PIFA can generate and operate in 1/8 wavelength resonant modes [3] for reducing antenna sizes compared to the traditional direct-fed PIFA (Ref2) exciting 1/4 wavelength resonant mode (5×23 mm^2). And it can be seen that the proposed two-layer thin-film capacitor can greatly reduce the required coupling area compared to the Ref1, therefore achieve a more compact antenna size (5×10 mm^2) than the Ref1 PIFA (5×15 mm^2). The simulated user's hand model comprises skin, muscle, and bones [2]. The user's hand is considered as a lossy medium with relatively higher dielectric constant, so it would cause some frequency shifting to the resonant mode, absorb antenna radiation power and cause pattern distortions. From the simulated results, it can be seen that for the case of proposed antenna with the hand, good impedance matching can still be achieved covering the desired frequencies. However, the radiation efficiencies will decay from 76% to 49% due to the energy absorption by the hand. More details about the antenna performance considering the user's hand will be presented and discussed in the conference.

4. Conclusion

An internal small-size thin-film smartwatch antenna design implemented by novel LITA technologies jointly developed by ITRI and ACON in Taiwan has been presented. Through the proposed LITA technologies, a compact 1/8 wavelength PIFA (5×10 mm^2 only) can be formed on the internal surface of a smartwatch casing successfully with conformal, thin-film type, multi-layer and highly integrating characteristics. The constructed antenna prototype shows that good antenna performance can be achieved successfully.

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