Printed 5G Reconfigurable Wireless Modules Using Additive Manufacturing Techniques

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***Abstract*—The overview of recent advances in additive manufacturing techniques such as different metallization methods is introduced. A fully printed 5G reconfigurable antenna is proposed. The fabrication process using 3D and inkjet printer is characterized. The flexible 3D printed material is used as the base substrate and the inkjet printed silver traces are used as the conductive traces. The operational frequency range of the proposed antenna can be changed by applying pressure on the flexible to change the shape of the structure. Thus, reconfigurability can be achieved. The center of the operational frequency can be adjusted between 26 GHz to 28.9 GHz. The adjusting rate is 11 %.**

I. Introduction

The additive manufacturing techniques such as inkjet printing and three-dimensional (3D) printing have become more and more popular in the last decade. The ability to accommodate more complex 3D structures as well as multi-material integration offers significant advantages to modern applications. The complex 3D structures can be used to improve the performances and achieve higher spatial efficiency. The multi-material integration and the flexible choices on the materials are important to accommodate the design to different applications and environments. For example, flexible materials are used for on-body application and low-loss materials are used for component design. Furthermore, the additive manufacturing techniques are low-cost and fast prototyping methods which are suitable for large-scale manufacture. Compared to conventional subtractive manufacturing techniques, additive manufacturing techniques use fewer materials and chemicals and thus are more friendly to the environment. Because of all advantages mentioned above, the additive manufacturing techniques have been used to realize high-performance RF systems [1]–[3], components [4]–[6], and 3D packagings [7].

One of the key challenges for additive manufacturing methods is metallization. There are three main approaches as shown in Fig. 1. The first one is to use electroless plating to deposit metal such as gold, silver, and copper on top of the surfaces [4]. This method is suitable for metalize large and complete area. However, it is not appropriate if specific patterns are required. The second one is to fabricate micro-channels and inject liquid metal into the channels [5], [6]. This is especially applicable to wire antenna designs but is not appropriate for specific patterns either. The third one is to inkjet print the patterns on top of the surface [7]. Compared with the other two choices, this method is suitable while specific patterns are required.

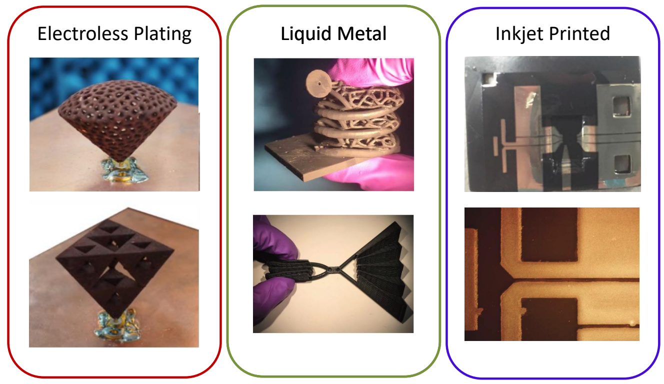

Fig. 1. Three ways for metallization on 3D printed substrates. [4]–[7]

Recently, additive manufacturing techniques are applied to solve the challenges of new 5G wireless modules. In [7], broadband package-integrated antenna and 3D package structures are realized using 3D and inkjet printing. However, most of the previous designs using printed metal traces as metallization method are not reconfigurable. Because of the 3D printed techniques and the flexible materials, additive manufacturing techniques are good candidates to achieve reconfigurable designs using structural reconfigurability.

In this paper, a fully additive manufactured 5G reconfigurable antenna is proposed. The structure is composed of a 3D printed L-shape flexible substrate, a thin layer of SU8, and a layer of inkjet printed silver as the conducting trace. The L-shape flexible substrate can be compressed to induce the operational frequency shift to the antenna. Thus, a wider frequency range can be covered with the proposed reconfigurable antenna. This is critical for the 5G application since a wide operational range is required for the 5G protocol to achieve a higher data rate.

II. Fabrication Process

The flow chart for the fabrication process is demonstrated in Fig. 2. The first step is to 3D printed a flexible L-shape substrate as the base. The 3D printer used is the stereolithography (SLA) 3D printer with z-direction resolution equals to

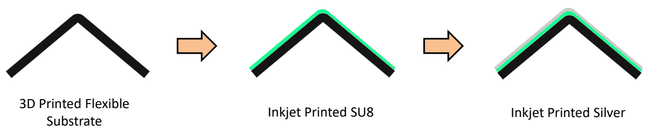

Fig. 2. The flow chart for the multi-material printing process.

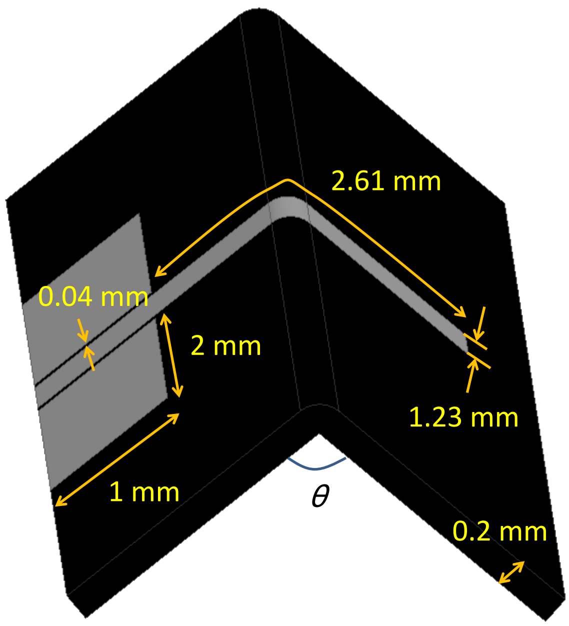

Fig. 3. The structure and dimensions for the reconfigurable antenna design.

50 µm. The flexible material (FLGR02) is characterized and the dielectric constant and loss tangent is 2.83 and 0.03 at 28 GHz, respectively. Then a layer of SU8 is inkjet printed on the top of the flexible material to alleviate the surface roughness as well as acts as an intermediate layer to balance the coefficient of thermal expansion (CTE) mismatch between the flexible material and the silver trace [7]. Finally, the silver traces are inkjet printed on the top of the SU8.

III. Reconfigurable Antenna Design

The structure of the proposed reconfigurable monopole antenna design is shown in Fig. 3. The physical dimensions are also included in the figure. The thickness for the substrate is 0.2 mm. The amplitude of the angle θ will change when applying pressure on the flexible substrate. The extreme value for the angle θ is between $60°$ and $120°$. The length of the monopole is kept at 2.61 mm no matter what θ is. The operational frequencies are changed while θ change. Thus, reconfigurability of the proposed antenna can be achieved.

The full-wave simulated results for the proposed structure under different θ are shown in Fig. 4. The center frequency is 26 GHz when θ is $120°$ and it changes to 28.9 GHz when θ is $60°$. The operational frequencies can be tuned by 11% by mechanically compressed the structure.

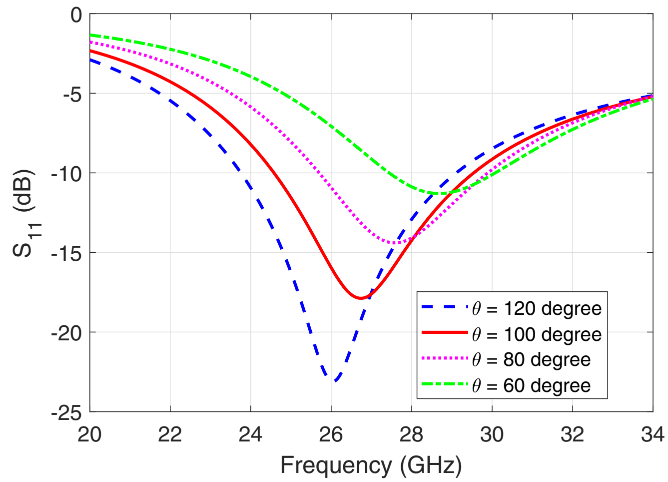

Fig. 4. The simulated scattering parameter for the proposed antenna.

IV. Conclusion

The recent advances in additive manufacturing techniques, as well as metallization approaches, are introduced. The first reconfigurable antenna using 3D printed flexible substrate and inkjet printed silver trace is proposed. The operational frequency band can be adjusted by applying pressure and caused the structural change in the design. The center frequency can be adjusted between 26 GHz and 28.9 GHz which is an 11 % tuning rate. The proposed fully printed reconfigurable antenna can be a good candidate for 5G applications.

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