Planar Monopole Antennas on Substrates Fabricated Through an Additive Manufacturing Process

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***Abstract* — This paper introduces a new method for creating a flexible antenna using additive manufacturing for the construction of the substrate. Two substrates were created using a 3D multi-material polymer printer. These substrates were composed using different ratios of the two materials supported by the printer. Planar monopole antennas with a bevel were placed on top of these substrates to form flexible antennas. This paper demonstrates a quick way to create antennas that can be used on non-rigid structures.**

***Index Terms* — Additive Manufacturing, Broadband Antennas, Flexible Antennas, 3D Printing.**

I. Introduction

Conformal antennas were initially developed to fit surfaces that were not flat, such as on the body of an aircraft. Installing an antenna on a curved surface was a major breakthrough, however, this was usually a rigid design. Flexible antennas have become a major topic of research to overcome this traditional rigidity and the potential applications range from wearable electronics, medical monitoring, and RFID [1-5].

The additive manufacturing process of 3D-Printing has further expanded the possibilities of antenna design. A few antennas have recently been constructed using 3D-Printing [6-11], however, these designs were not geared toward flexibility.

This paper incorporates the technology of 3D printing and flexible antennas. A flexible substrate is fabricated using 3D-printing and a planar beveled monopole antenna is situated on the surface.

II. Substrate fabrication

The matrix material of the flexible meander antenna is an epoxy based soft polymer, which was created by using a three-dimension (3D) multi-material polymer printer (Objet Connex 260, Stratasys, Edina, MN, USA). The printing process works by depositing droplets of polymer ink at ~70 ^{o}C, wiping them into a smooth film, and then UV photo-polymerizing the film.

The thermomechancial properties of the matrix can be tuned by adjusting the ingredient ratio of the polymer ink. Two types of soft polymers were used in this study (denoted as Tango Plus Black and Shore 85 respectively), and their temperature dependent storage modulus and Tanδ were measured in uniaxial tension dynamic mechanical analysis (DMA) test (frequency = 0.1 Hz; cooling rate = 2 °C/min; sample dimension 15 mm×6 mm×2 mm). As seen in Fig. 1, within the temperature range from - 50°C to 90 °C, the storage modulus far below the glass transition temperature (T_g) is about two orders of magnitude larger than that above T_g. The temperature corresponding to the peak of Tanδ is taken to be the T_g, and the measure value for these two soft matrix materials are respectively -5.1 °C and 30.1 °C.

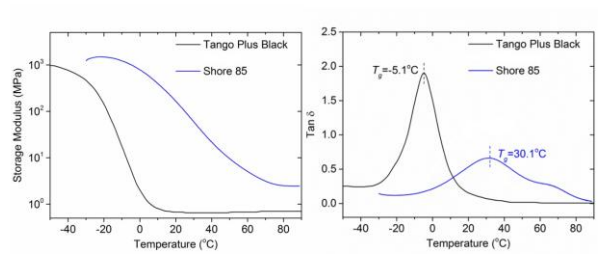

Fig. 1. Glass transition behavior of the flexible matrix.
(a) Temperature dependent storage (b) Temperature dependent Tanδ

Tango Plus Black is very flexible and Shore 85 is slightly more rigid at room temperature. A 6cm by 6cm square with a thickness of 1mm was created for each of the two chosen substrates with the 3D polymer printer. Fig. 2 demonstrates the difference in flexibility for the substrates under the force of gravity.

A rough estimate of the dielectric constant is needed to simulate the antenna. This was accomplished via a Two-Microstrip-Line-Method [12] for the two substrates. This analysis provides the effective permittivity of the microstrip line, and the relative permittivity can be calculated from this value. For both substrates, the calculated dielectric constant is around 3.

III. Antenna Design and Fabrication

A planar monopole antenna with a bevel was designed for this antenna using Computer Simulation Technology's

(CST) Studio Suite. A relative permittivity of 3 was employed for the substrate. The dimensions of the antenna are shown in Fig. 3. A ground plane was placed on the back of the substrate from the start of the feed and stopped 2mm from the start of the beveled edge. The antenna is broadband in nature, and was designed to start operation around 2GHz.

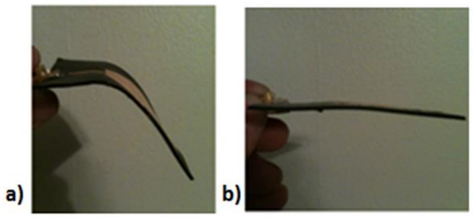

Fig. 2. Side by side view of the antennas under the force of gravity. a) Tango Black. b) Shore 85.

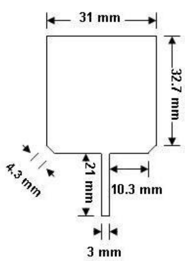

Fig. 3. Dimensions of the planar monopole antenna.

In an effort to maintain the flexibility of the antenna in this early stage of design, the substrate was metallized with copper tape. Fig. 4 shows the constructed antenna.

Fig. 4. Constructed flexible planar monopole antenna.

Fig. 5 demonstrates the flexible nature of the substrates. Due to the ratios of materials used to construct the substrates, the antennas possess different degrees of flexibility.

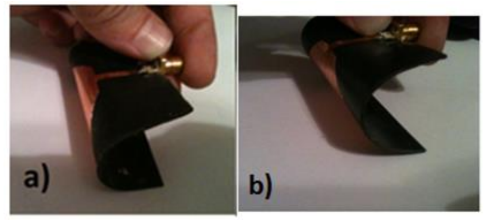

Fig. 5. Side by side folding of the two different substrates. a) Tango Black substrate. b) Shore 85 substrate.

IV. RESULTS

S11 testing for the two antennas was performed using a Rohde and Schwarz ZVA8 Vector Network Analyzer. Fig. 6 shows the magnitude of the S11 for the two antennas and the simulated results in the flat configuration.

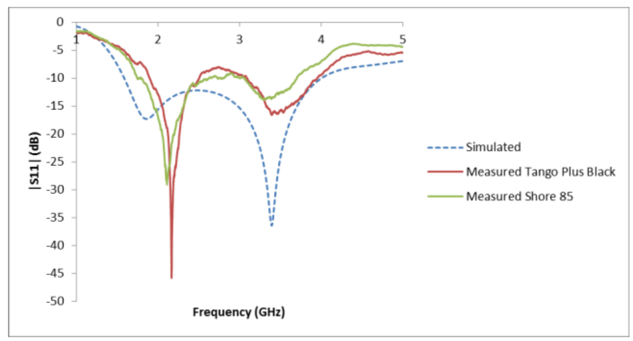

Fig. 6. Simulation versus physical measurements of the two flexible antennas when flat.

To test the effect of bending the antennas, each antenna was then flexed in the center of beveled component at a bend radius of approximately 10 mm and the S11 was again measured. Fig. 7 shows this data for both antennas and the simulations results.

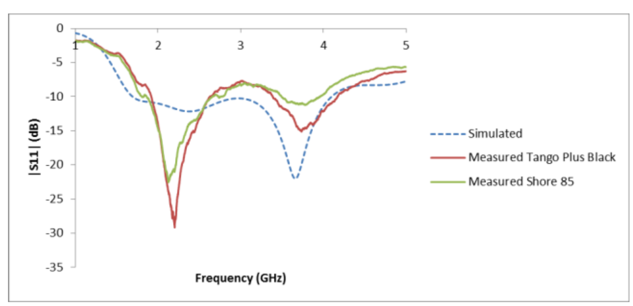

Fig. 7. S11 results from bending for all three antennas and the simulation results.

The voltage standing wave ratio (VSWR) for the flat configuration and folded configuration are shown in Fig. 8 and Fig. 9. This demonstrates the broadband nature of these antennas.

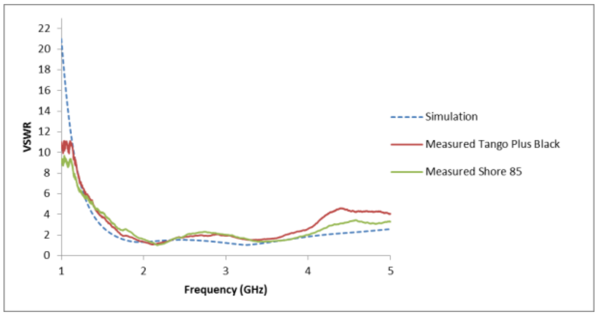

Fig. 8. VSWR for the flat configuration of the planar monopole antenna.

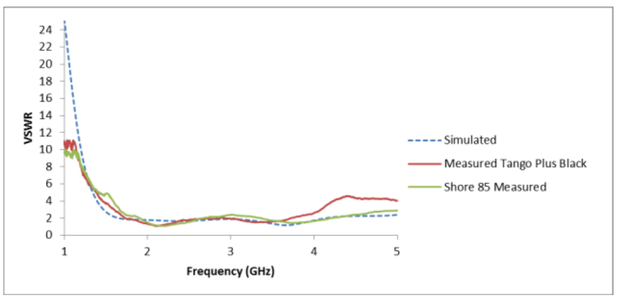

Fig. 9. VSWR for the folded configuration.

V. Conclusion

Flexible substrates were created with a 3D Printer and used to fabricate flexible planar monopole antennas. Tango Plus Black and Shore 85 were used for fabrication. This work demonstrates a quick and novel way to create antennas that can be used in any situation where a rigid antenna is not ideal.

Acknowledgement

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