Mechanical and Thermal Tests of Textile Antennas for Load Bearing Applications

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***Abstract*—In this paper we assess the mechanical and thermal performance of a load-bearing spiral antenna fabricated using conductive textile threads (E-threads). This textile spiral exhibits a nearly 10:1 bandwidth (0.3–3GHz) with circularly polarized gain of 6dBi across the 1–3GHz band. Such performance is unique for textiles and flexible surfaces. Mechanical tests for the spiral showed no appreciable changes in performance, even after 300 flexing cycles. Thermal tests were also performed at +90°C and -85°C. Again, the performance of the textile spiral remained almost unchanged. Overall, the proposed spiral exhibits excellent mechanical and thermal robustness. As such, it is attractive for several wideband, conformal, and load-bearing applications, even under extreme weather conditions (e.g., vehicular and airborne).**

Keywords—Archimedean spiral, conductive textiles, Kevlar fabric, embroidered antenna, mechanical testing, thermal testing.

I. INTRODUCTION

Broadband, conformal, and robust antennas are highly attractive for several vehicular, airborne, and wearable applications [1]-[4]. To address these requirements, we recently reported a new class of textile antennas based on automated embroidery of conductive textile threads (E-threads) [5], [6]. These embroidered surfaces are highly flexible and lightweight, and exhibit low conductor loss.

In this paper, for the first time, we assess the mechanical and thermal performance of textile antennas surfaces. Specifically, we consider an Archimedean spiral antenna printed on Kevlar fabric using conductive E-threads. Three point flexing tests were performed on the antenna for up to 300 cycles. Further, thermal storage tests were performed for 2 hours at the +90°C and -85°C temperatures. Our tests showed no appreciable changes in antenna performance.

I. SPIRAL ANTENNA: DESIGN AND PERFORMANCE

The proposed antenna is shown in Fig. 1. It is a 160mm-diameter Archimedean spiral, designed to operate from 0.3 to 3 GHz [1], [7], [8],[9]. To realize unidirectional radiation, a shallow reflecting cavity was employed. Specifically, the reflecting cavity was placed at a distance of $\lambda_{low}/40$ from the spiral surface, where λ_{low} refers to the wavelength at the lowest operational frequency (0.3 GHz).

The fabricated spiral prototype is shown in Fig. 1(b). The spiral and ground plane were 'printed' on textiles. This was done using automated embroidery of 7-filament silver-plated copper Elektrisola E-threads [10]. These E-threads are very thin (diameter ≈ 0.12mm) and can achieve embroidery accuracy as high as 0.1 mm, viz. similar to typical Printed Circuit Board (PCB) prototypes [6]. A Kevlar fabric was used to 'couch' the spiral, because of its suitability for extreme and flexible applications. The spiral was fed at its center via a differential feed [1]. As in [1], [8], [9], two 180 Ω resistors were soldered at the spiral ends to suppress wave reflections.

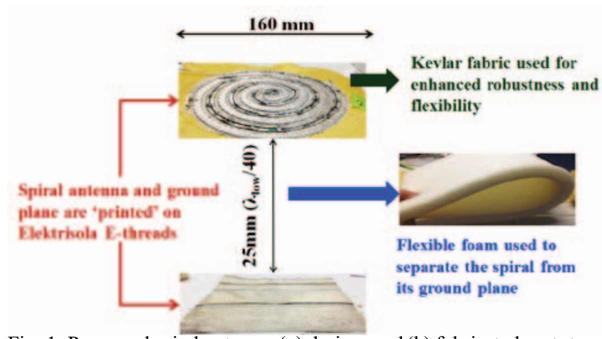

Fig. 1. Proposed spiral antenna: (a) design, and (b) fabricated prototype.

Measurements of the antenna voltage standing wave ratio (VSWR) exhibits a 10:1 bandwidth (VSWR < 2), operating from 0.3 to 3 GHz. The measured boresight gain is shown in Fig. 2 ('before flexing'). As seen, the LHCP (co pol.) was around 6dBi across the 1 to 3 GHz band. The RHCP (cross pol.) radiation was very low and as much as 15dB below the co-pol gain. As a result, a low axial ratio was achieved.

II. MECHANICAL TESTING

Three point flexing tests were carried out to assess the mechanical performance of the textile spiral shown in Fig. 1. To do so, we placed the antenna flat upon two supporting pins, at a distance of 160 mm. A third pin was then lowered from above at a speed of 50 mm/min to bend the antenna. The maximum bending angle was 100°. Fig. 2 shows the measured boresight realized gain of the textile spiral after 300 bending cycles. As seen, the performance remains nearly the same before and after flexing.

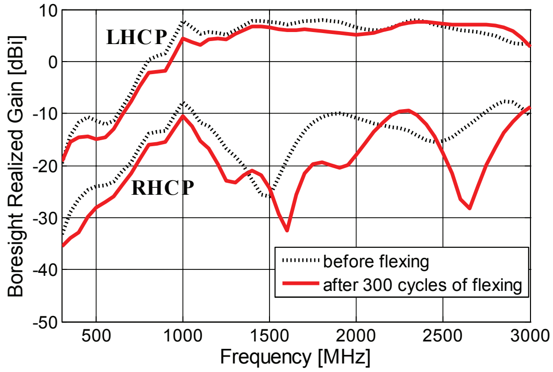

Fig. 2. Boresight realized gain of the textile spiral before and after 300 cycles of flexing.

III. THERMAL TESTING

To assess the thermal performance of the textile spiral, we carried out hot (+90^{o}C) and cold (-85^{o}C) storage tests based on [11]. The heating/freezing process was as follows: 1) Place antenna in hot/cold chamber (oven/freezer); 2) Gradually adjust the chamber temperature to the target value, at a speed no faster than 3^{o}C/min; 3) Keep target temperature steady for 2 hours; 4) Adjust chamber to room temperature; 5) Take antenna outside the chamber and measure its performance.

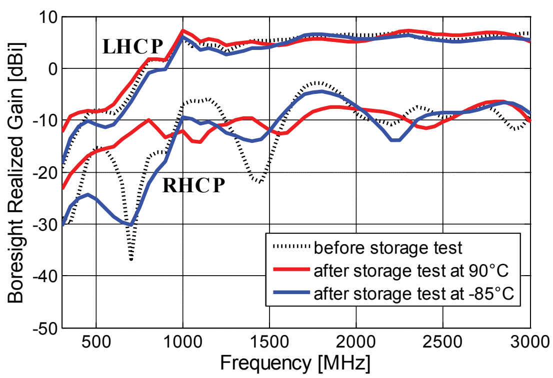

Fig. 3. Boresight realized gain of the textile spiral before and after hot (+90^{o}C) and cold (-85^{o}C) storage tests.

Measurement results before and after the hot (+90^{o}C) and cold (-85^{o}C) storage tests are shown in Fig. 3. As seen, the antenna performance again remained nearly unchanged. There were also no obvious indications of any deformation or damage to the antenna structure.

IV. CONCLUSION

We assessed the mechanical and thermal performance of a flexible textile spiral antenna. The antenna also included a textile ground plane and was fed by thin coaxial cable wound on the spiral's conductive surface as in [7]. The entire antenna was embroidered using a new class of Elektrisola E-threads on Kevlar fabrics. It exhibited a nearly 10:1 bandwidth (0.3–3GHz) with circularly polarized gain of 6dBi across the 1–3GHz band. Remarkably, the spiral showed non-appreciable changes in performance, even after 300 flexing cycles, and after 2-hour thermal heating at +90^{o}C and cooling at-85^{o}C. As such, the proposed spiral is very attractive for several wideband, conformal, and load-bearing applications, even under extreme weather conditions (e.g., vehicular, airborne).

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