Flexible Spiral Antenna with Microstrip Tapered Infinite Balun for Wearable Applications

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***Abstract*—In this paper we introduce a flexible, side-fed, ultra-wideband, spiral antenna with an integrated microstrip tapered infinite balun operating from 1-5GHz. It was fabricated using Rogers 5880 subtrate and specially coated to prevent oxidization. The simulation and measurements match quite well with S11 below -10dB throughout the frequency range and gain of close to 5dB and average efficiency of 65%. Most importantly, this antenna does not have an obtrusive center feed, and instead has a side feed, is flexible, compact, rendering many possible wearable antenna applications.**

I. INTRODUCTION

Spiral antennas have many advantages for wearable applications, including circular polarization, low-profile planar form factor, and wide frequency band characteristics. However, one of the major disadvantages is designing the feed due to the high impedance, the need for a balun, and the obstructive nature of the perpendicular feed connection which prevents its usage towards wearable applications. To overcome these obstacles, it is important to address not only the feed, but also the flexibility of the antenna. In this paper, we introduce a side-fed, flexible, ultra-wideband spiral antenna operating from 1 to 5GHz.

The concept of side-fed spiral antennas is well known [1,2], and the feed with microstrip tapered infinite balun combines the concept of the infinite balun [3,4] with proper impedance matching. However, the differences are first the use of flexible Rogers material, and secondly the use of one arm of the spiral antenna as the ground for a microstrip transmission line, which is the novelty. This design provides a wide-band, planar and easy to fabricate balun and therefore constitutes a practical solution for antenna systems using spiral antennas.

The infinite balun used in many papers for spiral (slot) antennas basically consists of a coaxial cable spiraled along the antenna arms with the coaxial shield soldered to the antenna arm. At the center, the coaxial pin connects to the other antenna arm. This balun construction only provides balance-unbalance transformation, but no impedance matching. Due to the typically high input impedance of spiral antennas, an infinite balun alone is not suitable for practical applications. On the other hand, it is well known that a tapered microstrip line can be used for impedance transformation. In the following sections, the microstrip tapered infinite balun design is introduced on a flexible substrate for wearable antenna applications.

II. DESIGN AND FABRICATION

The novelty of this design is that one arm of the spiral antenna is used as ground for a microstrip transmission line and the conductor of the microstrip is printed on the other side of the substrate. The microstrip conductor spirals inwards from the outer edge of the spiral antenna to its center, always over the middle of the spiral arm which serves as ground plane. In the center, the microstrip conductor is connected to the other spiral arm. A second, non-connected microstrip conductor has been placed above this second spiral arm for symmetry purposes. This setup is depicted in figure 1 below.

For the substrate, wearable applications were the main application, so a flexible Rogers RT/Duroid 5880 TM substrate was used (εr = 2:2; h = 2 mil = 0:508mm). The design parameters can be calculated from the microstrip equations 5.1 and 5.2 [5]. For this substrate, a microstrip width between 60.75 mil (50 side) and 3.61 mil (165 side) has been calculated.

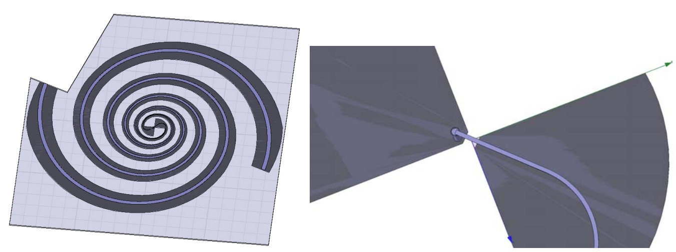

Figure 1. HFSS simulation of (a) microstrip tapered infinite balun feed for planar log spiral (b) Magnified view of the center connection.

To fabricate the design, a prototype of the simulated design has been manufactured with a copper cladding of 0.5 oz (per square foot) and an electroless nickel with immersion gold (ENIG) coating to protect the surface from oxidation and

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facilitate soldering. The dimensions are 4x4 inches with thickness 2 mils. The fabricated prototype is shown in figure 2.

Figure 2. Prototype (left) top view with log spiral antenna (right) bottom view with the tapered microstrip balun.

III. Measurement Results

The antenna prototype has been measured at SATIMO, and the simulated and measured S11 results are plotted in figure 3 below. A ripple effect is visible in the measurement data, which is not present in the simulation results. One possible explanation for this discrepancy could be that the coaxial connector introduced a ripple that did not show up in the simulation results since the simulation model did not consider the coaxial connector. In the actual prototype, it is likely that reflections occur due to this connection.

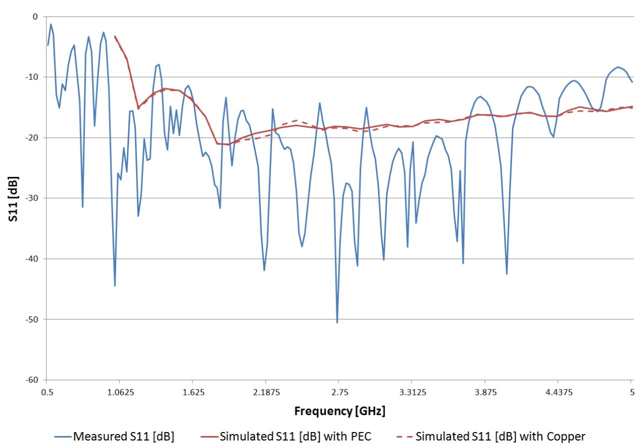

Figure 3. Measured vs. simulated S_{11}.

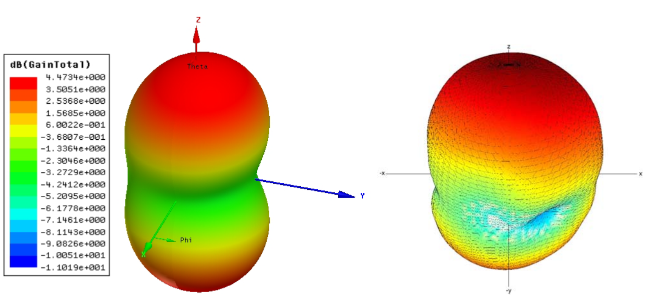

Figure 4. Simulated (left) vs. measured (right) 3D gain pattern at 2.46GHz, where measured gave max 3.07dB gain.

The radiation pattern measurements show very close match with the simulation as can be shown in figure 4. The gain measurements show that the gain is 4.47dB compared to 3.07dB at frequency 2.46GHz. In figure 5, throughout the frequencies from 1 to 5GHz, the gain is mostly between 0dB and 5dB.

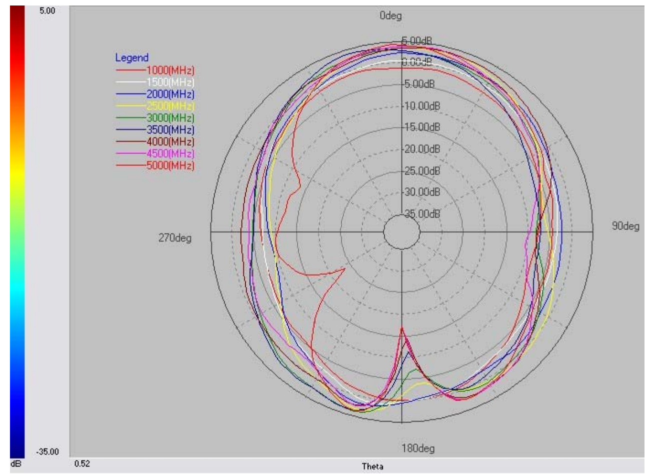

Figure 5. Measured gain pattern of prototype antenna, frequency varied.

Efficiency measurements indicate values ranging from 75% to 50% throughout the bands with an average of 65% efficiency.

IV. Conclusion

In this paper, a flexible, side-fed, ultra-wideband, spiral antenna with a microstrip tapered infinite balun feed has been presented operating from 1GHz to 5GHz with gain ranging from 0 to 5dB. The significance of this design is that, coupled with an EBG surface this design can be used towards wearable applications due to the side-feed, as opposed to the obstructive perpendicular feed, as well as the flexible nature of the Rogers substrate used.

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