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Simulation Methodology to Model the Behavior of Wearable Antennas Composed of Embroidered Conductive Threads

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Wearable antennas have many potential applications including the emergency services, fashion, military, athlete and patient monitoring. However, as yet they have had limited success in being adopted by the general public. This is partly due to the fact they look and feel awkward as well as being electromagnetically inefficient. An exciting technique of circumventing these problems is to replace the flexible conductive materials with conductive threads which will potentially allow the antenna to be created as an intrinsic part of the clothing. Embroidering the threads will negate the need for adhesives and will allow the clothing to be washed. Furthermore, industrial embroidery machinery will allow this smart clothing to be manufactured on a large commercial scale.

Conventional antennas can be simulated using continuous metallic sections. However, the behavior of antennas fabricated with conductive threads is more complicated. The authors have shown that embroidered transmission lines have better S21 results when the stitch direction is parallel to the line as opposed to perpendicular to it – see figure (Acti et al, LAPC 2011). This demonstrates that the resistance along the thread is less than from thread to thread and hence the stitching direction and stitch density can be used to control the current flow and hence the antenna performance. The authors have measured the electromagnetic performance of embroidered patch antennas with different stitch directions and have shown that the efficiency is altered (Chauraya et al, EUCAP 2012).

Therefore, a more detailed simulation methodology is required to model the discrete and directional nature of the threads (see figure). These structures can be simulated by using thin (0.1mm) strips with a lower conductivity to represent the gap between threads. The most suitable value of the conductivity of these strips will depend on the stitch density, the conducting thread material and the level of oxidization on the metallic surfaces. Simulated results mirrored the previous measurements that the direction of the threads is critical to the antenna performance. Changing the conductivity in the 'gaps', altered the current density and current direction. Using a conductivity of 1000S/m in the 'gaps' reduced the efficiency to 28.8% and the gain to 1.77dBi compared to 40% and 3.23dBi for the copper version.