Textile Antenna Arrays and their Environmental Durability

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Ultra-wideband (UWB) antennas are of great interest for radio sensing and communication systems as they can seamlessly integrate several narrowband radios into a single multi-functional platform. Recently developed UWB phased arrays using tightly coupled dipole elements have demonstrated extremely wide bandwidths >30:1 (J. Zhong, et. al, "Ultra-Wideband Tightly Coupled Dipole Array with FSS R-Card," IEEE APS/URSI 2018), in addition to wide angle spatial scanning >70° (E. Yetisir, et. al, "Ultra-wideband Array with 70° Scanning using FSS Superstrate", IEEE AWPL, 2016) and spatial multiplexing; a much needed feature for beamforming applications. Importantly, these tightly coupled dipole arrays (TCDAs) are low profile and can be inconspicuously mounted on any surface. Further, fabrication of low profile UWB arrays with small footprints offer notable reduction in power, cost, and space for the radio, communication, and sensor systems. These attractive features make low profile wideband antenna array a key component in high data rate communications and high resolution radar.

The wide bandwidth performance of the TCDA owes to the their integrated balun feeding network which serves as a higher order impedance matching network. So far, TCDAs have been implemented and validated from 0.3 GHz (UHF) up to 90 GHz (W-band). Nevertheless, until now, TCDAs have only been printed utilizing printed circuit board (PCB) processes. This provides a rigid and electrically stable structure. However, PCBs are known for their fragility, with the possibility for snapping and losing electrical connection under stress. In addition, as array size grows, these traditional arrays become expensive and bulky, requiring extreme spatial needs even in storage. The aforementioned drawbacks of antenna PCB fabrication can be mitigated when a flexible and durable substrate is employed for antenna array fabrication. Fabrication of TCDAs on textiles, as opposed to PCBs, allows the array to be foldable and packable, deployable, and crushed by loads while still being able to operate. The development a suitable textile technology will allow the accuracy of operation that comes with a PCB design, with the advantages of a textile substrate.

Multiple environmental tests have been conducted to evaluate the performance of different textile substrates (denim, organza, and wool) with extended water damping and after multiple drying cycles. To do so, simple patch antennas were designed using conductive thread on either denim, organza, or wool. Each antenna was first damped in tap water and measured. Then, the antenna was measured at different time intervals that extended up to 24 hours. Results show that only with denim, were we able to recover the original performance of the antenna. At the conference, we will present a wideband characterization of various textile materials and the impact of water damping and drying, physical folding, stretching, and twisting. In particular interest, we will characterize the permittivity of a multilayer denim substrate with integrated layer of fabric-like stabilizer. This characterization is a necessary step to accurately model future multi-layer antennas such as textile TCDA. Additionally, a comparison between the use of conductive ink on textile substrates and embroidery processes will be presented.