Active textile multi-antenna systems for energy-efficient body-centric communication

The last decade, we have witnessed a tremendous evolution in sensor networks deployed on the human body. Nodes in such a body area network monitor different life signs of the wearer, as well as environmental conditions. In addition, they exchange information and communicate wirelessly to a remote monitoring station or command post, which, in turn, feeds back commands, warnings or alarms. A well-known issue is the power consumption of these body-centric smart systems, requiring heavy batteries that may cause discomfort to the wearer and that require frequent recharging. In particular, the wireless communication module is one of the main consumers of energy in each sensor node.

In this contribution, we review active textile multi-antenna systems as a means to reduce the power-consumption while maintaining reliable communication in wireless off-body links. The key idea is that a garment offers a large platform, in which one can easily deploy multiple antennas of sufficient size to provide high gain and large radiation efficiency in the presence of a human body. Yet, it is important that this multi-antenna system does not disturb the movements or the comfort of the wearer. Hence, the antennas should be low-weight, flexible and breathable. Therefore, we fabricate the antennas using the same materials as found in the garments, allowing seamless integration. The active electronics circuits, such as the transceiver, sensors and battery, are then placed on a small flexible polyimide carrier, such that they may be integrated directly underneath the textile antenna's ground plane, resulting in a compact flexible module. Each active antenna module is optimized to yield maximum performance and minimal energy consumption by adopting a dedicated full-wave/circuit co-design strategy. Next, we apply multiple-input multiple-output (MIMO) techniques to create highly reliable wireless off-body links at reduced transmit power. It will be shown that, both for Line-of-Sight as for non-Line-of-Sight propagation, in most cases beamforming at the transmit side yields lower bit error rates than space-time coding, provided some diversity gain is implemented at the receive side. In addition, it will be demonstrated that high diversity orders can only be obtained by means of space-time coding provided that highly reliable channel estimates are available at the receiver side. Data-driven channel tracking may be applied by the receiver to obtain such channel estimates without excessive overhead in terms of pilot symbols. Finally, we consider cooperative communication techniques to set up reliable connections between an implanted antenna and a remote monitoring station. A wearable on-body antenna system will be presented that serves as a repeater, reliably relaying the data from the implanted antenna to a remote access point, while allowing the implanted system to operate at low power.