Investigation of Creeping Wave Propagations Around the Human Head and Neck at ISM Frequency Bands

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The research idea of using time-variant wireless on-body channels as a method of characterizing motion activities of a human body has gained increasing interest in recent years. This low-cost and power-efficient approach promises great utility for a number of diverse applications in a wide array of industries, such as remote monitoring of vital signs like heart rate or breathing patterns, recognition of harmful maneuvers or stresses on soldiers or pilots in military training, and interaction between human and wearable devices like the smart phone and watches. To help characterize on-body propagation channels, Xue *et. al.* [*Xue, et. al., IET Microw. Antennas Propag, pp.1-7, April 2016*] has investigated the LOS and NLOS surface wave around a stationary human torso, and has applied an analytical model based on the creeping wave theory of Wait [*Wait, IRE Trans. Antennas Propag., pp. 445-448, 1960.*]. Alves *et. al.* [*Alves, et. al., IEEE Trans. On Antennas and Propagation, vol. 59, no. 4, pp. 1269-1274, April 2011*] has derived a general model for the theoretical creeping wave around the curved surface of the human body. However, the propagation effects of creeping waves traversing the human head and neck remain to be investigated. The objectives of this study are to achieve a fundamental understanding of how creeping waves propagate around the human head and neck at the ISM frequency bands, determine the dominant propagation path, and extract its associated propagation constant and decay rate.

In this work, we first measure the NLOS creeping wave propagation effects of three different paths encompassing the human head and neck (around the head, over the head, and around the neck) across three different frequencies (433 MHz, 915 MHz, and 2.45 GHz). One male and one female test subject are used. The test subjects are standing upright in an indoor, open hallway environment and remaining still for the duration of the test. Two quarter-wave monopole antennas pointing normal to the body surface are employed in the measurement: as the receiving antenna is moved away from the transmitting antenna, broadband transmission data S_{21} are recorded with an Agilent PNA-L vector network analyzer. The measured magnitude and phase data show fairly good agreement with theoretical models of the creeping wave described by Alves *et. al.*. The measurements are also compared to full-wave simulations modelling the same test setup as the experiments. Finally, we compare the creeping wave propagation around the head and neck to that of around the human torso, as reported by Xue.