

## Quality Assessment of Alternative Beams in Indoor and Outdoor Environments at 28 GHz

A. Bhardwaj, C. Loo, T. M. Villageois, P. Zarei, H. Noori  
and D. G. Michelson\*

University of British Columbia, Dept. of Electrical and Computer Engineering,  
Vancouver, BC, Canada

Université de Pierre et Marie Curie, Paris, France

At millimetre-wave frequencies, directional antennas are commonly used to ensure adequate received signal. When the direct path is blocked or not available, communication will be conducted by secondary paths that arise from reflection or scattering in the environment. Path loss and range of coverage at millimetre-wave frequencies has been studied previously but few if any results capture the relative capability of primary and secondary beams. Previous standards, e.g., IEEE 802.15.3c, IEEE 802.11ad, and WirelessHD, have assumed that secondary beams exist but few previous works have considered their quality and capacity. The number and quality of these secondary paths is of great interest but has not been previously characterized. Here, we seek to statistically assess the number and quality of the secondary paths in a variety of indoor and outdoor environments. To the best of our knowledge, ours is the first study to assess the relative quality and capacity of primary and secondary beams at millimetre-wave frequencies and, as a consequence, the performance that can be achieved when using beam forming in radio access environments.

Our beam quality assessment channel sounder uses various means to speed up the measurement process compared to an exhaustive search for all beams. It still takes almost an hour to assess the performance of alternative beams between two points with the three-dimensional (D2I) case taking 50% longer than the two-dimensional (D2D) case. We present the results as distributions/box plots that compare Pathloss, Ricean K-factor, and SISO/MIMO channel capacity for each of the  $n$  strongest beams. Our results show that the quality and capacity of secondary (reflected) beams at mmWave frequencies is dramatically lower than the primary (LoS) beam with results obtained in outdoor microcell environments to be significantly worse than in indoor environments of comparable size. Our results further suggest that the utility of switching to a secondary (reflected) beam when the primary (LoS) beam is blocked is somewhat limited in outdoor, indoor and hallway environments. These results may explain the failure of WirelessHD, a pioneering 60 GHz WPAN technology, that was introduced commercially ten years ago but almost immediately withdrawn from the market.