

## ABSTRACT

*The rapid growth of wireless telecommunications in densely populated areas has encouraged the adoption of Massive MIMO and 3D beamforming technologies to enhance network capacity and spectral efficiency. 3D beamforming allows signal transmission to be directed in three dimensions and is implemented in Virtual Small Cell (VSC) systems, particularly Direct VSC. In this scenario, the Base Station (BS) serves multiple User Equipment (UE) within a geographic cluster. However, high inter-layer channel correlation often leads to interference and performance degradation. This study evaluates the performance of MMSE, ZF, and MRT precoding algorithms in a 3D beamforming Massive MIMO system under the Direct VSC model using MATLAB simulations. Results show that MMSE achieves the highest performance with an average SINR of 28.1 dB and bandwidth efficiency of 9.34 bps/Hz, followed closely by ZF at 27.84 dB and 9.25 bps/Hz. MRT performs the lowest, with an SINR of 4.43 dB and bandwidth efficiency of 1.91 bps/Hz. The average received power for all methods is around -41.4 dBm, affected mainly by the BS and UE distance. In conclusion, MMSE offers the best performance in terms of SINR and bandwidth efficiency, followed by ZF, while MRT falls significantly behind both.*

**Keywords:** 3D Beamforming, Interference, Massive-MIMO, Precoding, Virtual Small Cell (VSC)