

## Multi-Gbps Massive MIMO for Future Smartphones and MIMO System Performance Verification

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Massive MIMO (Multi-Input Multi-output) has been shown to be promising for application in next-generation mobile devices such as the smartphone for 5G communications. Multi-Gbps MIMO throughput for the smartphone has also recently achieved. It has been demonstrated that with 12 antennas embedded in the limited space in the smartphone, 3.8-Gbps throughput can be obtained for 12 x 8 MIMO operation with 100-MHz bandwidth and 256-QAM modulation (see the results shown in Fig. 1). A spectrum efficiency of 38 bps/Hz in the smartphone side for the MIMO operation is obtained. In addition, with the user's hand covering all antennas in the MIMO array (a worst case for user's hand loading), a throughput of 2.76 Gbps with 100-MHz bandwidth and 64-QAM modulation has been obtained.

The 12 MIMO antennas operate in the 3.5 GHz band (3.4~3.6 GHz), a frequency spectrum recently identified in WRC-15 for global mobile broadband services and is a promising candidate for the fifth-generation communication. The 12 antennas are formed by six compact two-antenna building blocks with inherent decoupling structures, making it simple in structure, easy to fabricate, and occupying a very small volume in the smartphone (for example, K.-L. Wong, C.-Y. Tsai, and J.-Y. Lu, IEEE Trans. Antennas Propag., 65, Apr. 2017). The measured MIMO capacity and throughput are obtained using an in-house developed MIMO verification testbed. Operating principle of the MIMO antennas will be addressed. Detailed results of the multi-Gbps MIMO throughput for the 12-antenna smartphone in typical indoor and outdoor propagation scenarios will be presented. The obtained results indicate that the Massive MIMO operation with as many as 12 antennas in the smartphone is promising to implement and the multi-Gbps data transmission can be obtained with the inclusion of the user's hand for practical applications.





f = 3500 MHz (BW = 100 MHz), Power = 20 dBm, Distance = 2.5 m				
12 x 8 MIMO Scenarios				
	Free space	User's hand covers 4 antennas	User's hand covers 8 antennas	User's hand covers all 12 antennas
Modulation	256-QAM	256-QAM	256/64-QAM	256/64-QAM
SNR	23.0 dB (256-QAM) (20.6~24.5 dB)	22.3 dB (256-QAM) (19.8~24.3 dB)	20.55 dB (64-QAM) (15.6~24.2 dB)	16.93 dB (64-QAM) (13.3~19.2 dB)
Calculated Capacity	60.67 bps/Hz	59.20 bps/Hz	53.57 bps/Hz	44.80 bps/Hz
Measured Capacity	54.40 bps/Hz (0.896 x 60.67)	50.87 bps/Hz (0.859 x 59.20)	45.30 bps/Hz (0.845 x 53.57)	35.49 bps/Hz (0.792 x 44.80)
BER	0.046	0.082	0.126/0.03	0.186/0.07
Throughput	3776.8 Mbps	3632.6 Mbps	3461/2878 Mbps	3221/2761 Mbps
Spectrum Efficiency	37.8 bps/Hz (256-QAM)	36.3 bps/Hz (256-QAM)	28.8 bps/Hz (64-QAM)	27.6 bps/Hz (64-QAM)

Figure 1. Measured channel capacity and throughput of a 12-antenna smartphone in a 12 x 8 MIMO system.