CHAPTER FOUR
Results and Discussion

4.1 Introduction

In this chapter, a numerical results will be presented, to evaluate the SNR values with the increasing distance and to examine the effect of MIMO technology in increasing the capacity and data rate for a given distance.

4.2 Numerical analysis and Discussion

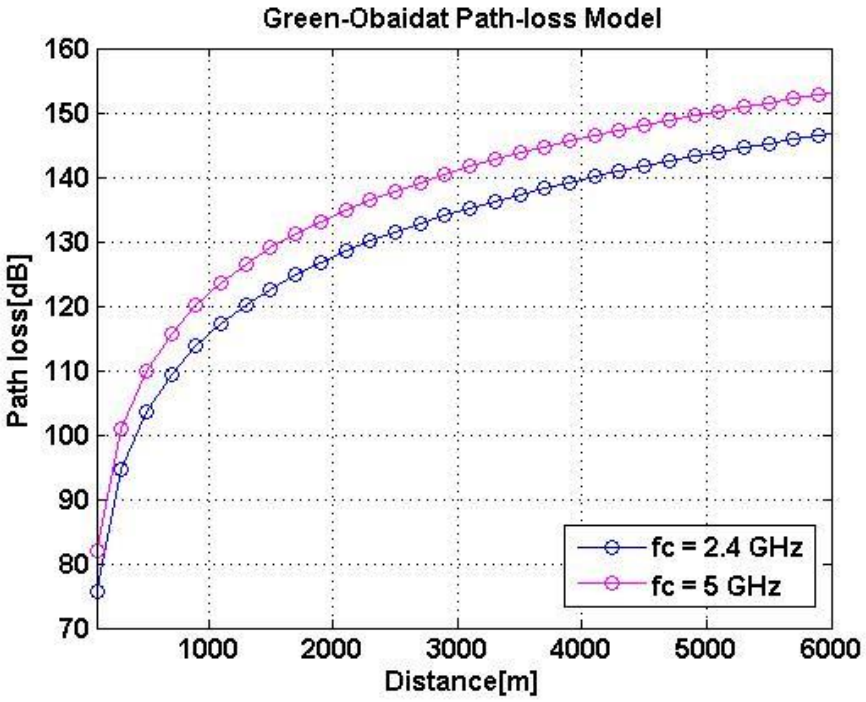
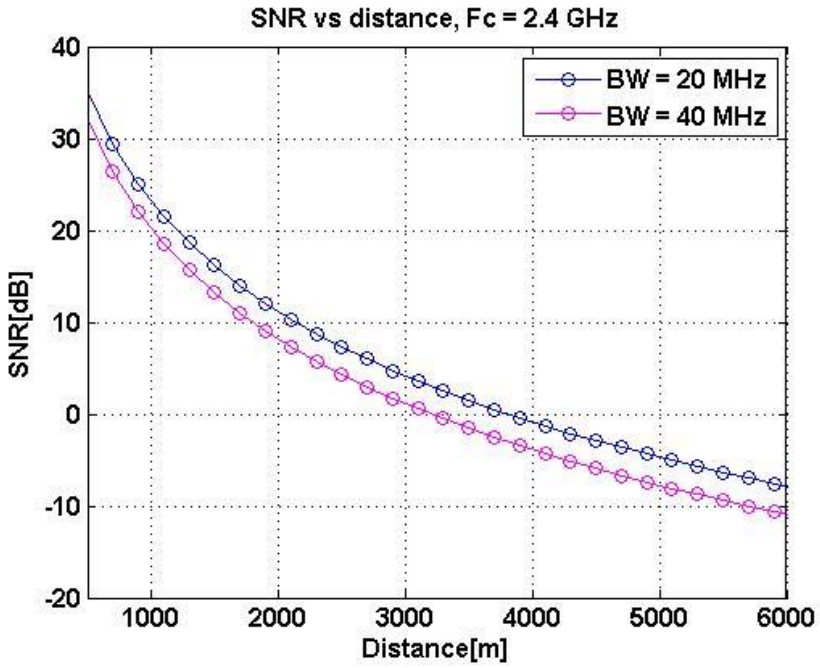
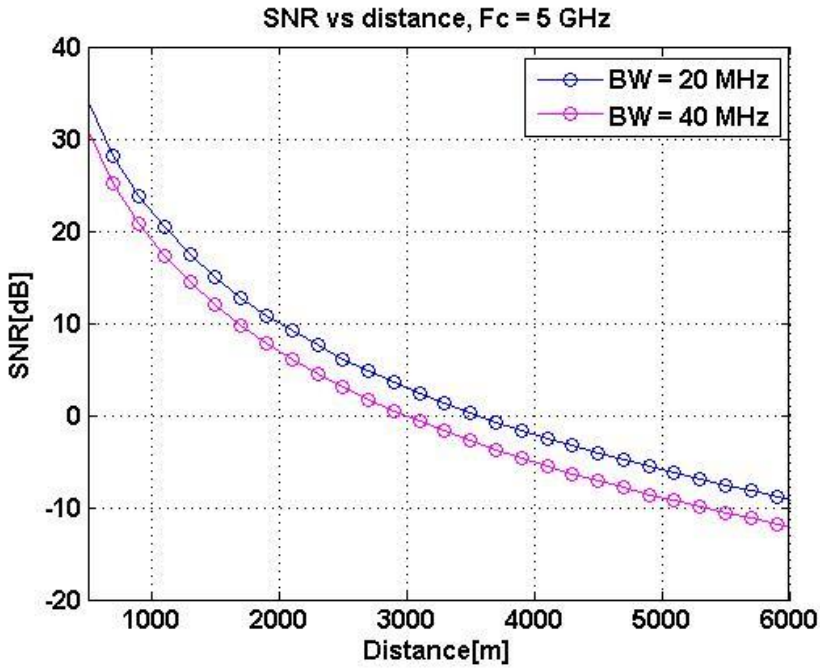


Figure 4-1: Green-Obaidat Path-loss Model

Figure 4-1 illustrate the variations of path loss values in 802.11n frequencies with increasing distance. The value of path loss when using 2.4GHz & 5GHz for 5km distance has been compared, The result of comparison show that the value of path loss at frequency 2.4 GHz is equal to 144 dB and the value of path loss at frequency 5 GHz is equal to150dB . From the result the value of using 2.4GHz has path loss less than 5GHz.



(a)



(b)

Figure 4-2: Comparison of Variation of SNR with Increasing Distances for a) Fc = 2.4 GHz b) Fc = 05GHz

Figure 4-2 shows the variation of SNR with increasing distances in four cases ,in table 4.1 below is showing the SNR values at these four cases with distance is equal to 5Km.

Table 4-1: SNR Cases

Cases	FC(GHz)	BW(MHz)	SNR(dB)
Case 1	2.4	20	-5
Case 2	2.4	40	-8
Case 3	5	20	-6
Case 4	5	40	-9

From table 4-1 the value of SNR is at highest value when using 2.4GHz frequency and 20MHz Bandwidth.

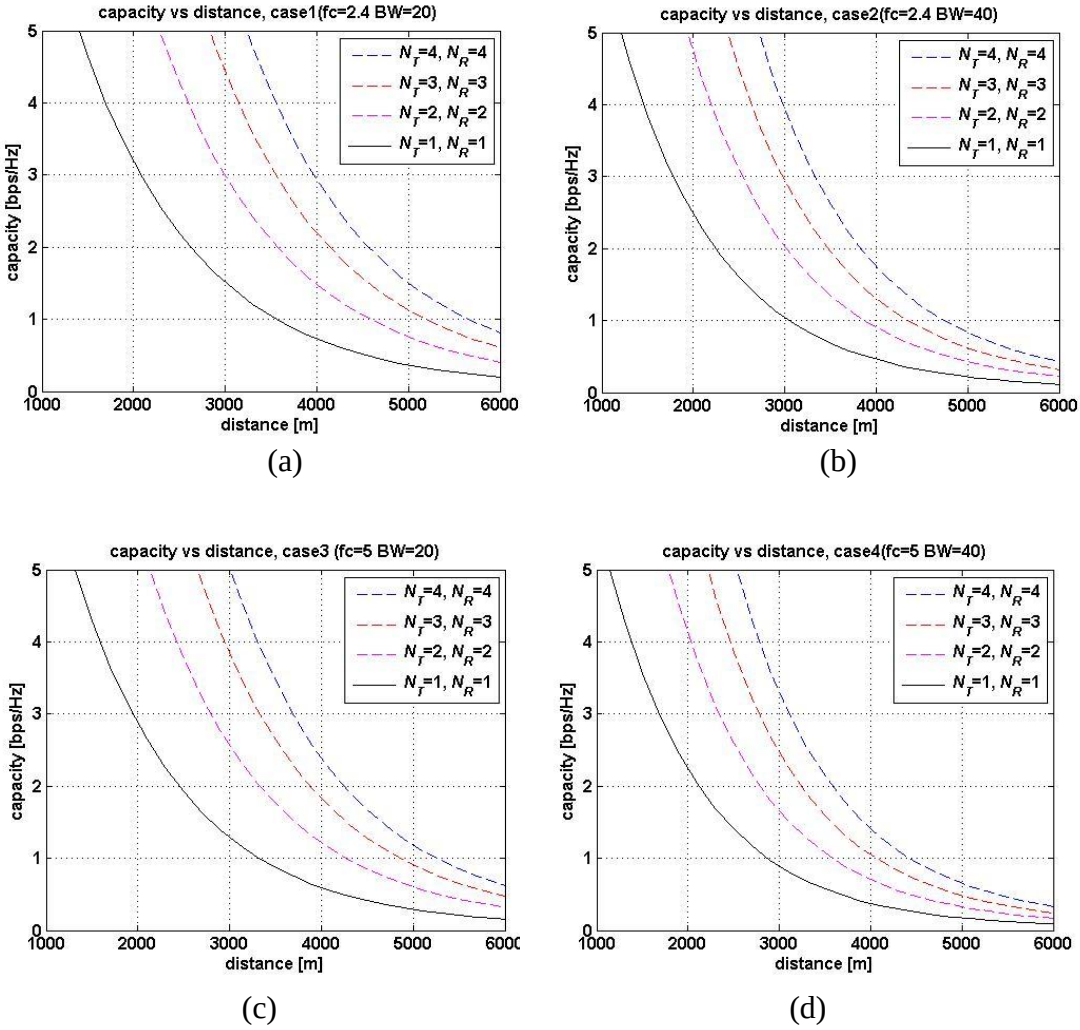


Figure 4-3: Capacity vs. Distance for SISO and MIMO Antenna System for

a) Case 1 b) Case 2 c) Case 3 d) Case 4

Figure 4-2 illustrate the variations of capacity with increasing distances for a single antenna system, and multiple antenna systems, we can notice the variation with the four cases of SNR values that was mentioned in the previous section. We compared the capacity values at 5Km distance, and the result is shown in table 4-2 below.

Table 4-2: Capacity Values for SISO and MIMO Systems at 5 km

Fc (GHz)	BW (MHz)	SISO(1×1) Capacity b/s/Hz	MIMO(2×2) Capacity b/s/Hz	MIMO(3×3) Capacity b/s/Hz	MIMO(4×4) Capacity b/s/Hz
CASE 1		0.38	0.77	1.13	1.50
2.4	20				
CASE 2		0.22	0.42	0.64	0.83
2.4	40				
CASE 3		0.30	0.61	0.90	1.20
5	20				
CASE 4		0.17	0.33	0.50	0.66
5	40				

A number of observations can be made from the figure 4-3 and the table 4-2 above. The highest values of capacity can be obtained by using the parameter in Case 1. As expected the range increase for the 4 × 4 MIMO system is significantly larger than for the 3×3and 2 × 2 system. In figure 4-3(a) for example, when operating at a capacity of 1 bits/sec/Hz we have ranges of 3700 meters, 4600 meters , 5200 meters and 5600 meters respectively, for SISO, 2 × 2 MIMO, 3 × 3 MIMO and 4 × 4 MIMO.

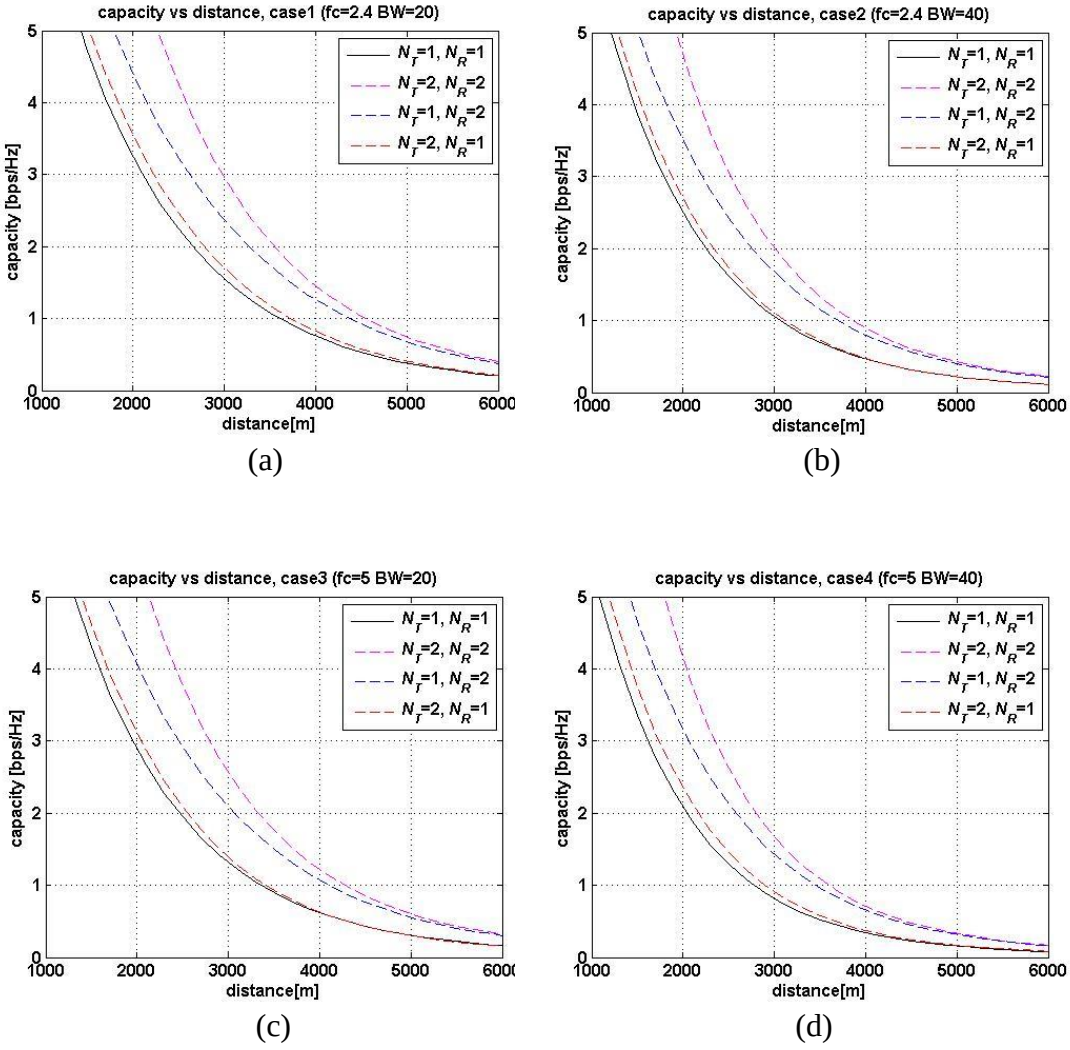


Figure 4-4: Capacity vs. Distance for SISO, SIMO, MISO and MIMO Antenna System for a) Case 1 b) Case 2 c) Case 3 d) Case 4

Figure 4-4 shows the variations of capacity with increasing distances for SISO, SIMO, MISO and MIMO antenna systems, we can notice the variation with the four cases of SNR values that was mentioned in the section above. We compared the capacity values at 5Km distance, and the result is shown in table 4-3 below.

Table 4-3: Capacity Values for SISO, SIMO, MISO and MIMO Systems at 5 km

Fc (GHz)	BW (MHz)	SISO(1×1) Capacity b/s/Hz	SIMO(1×2) Capacity b/s/Hz	MISO(2×1) Capacity b/s/Hz	MIMO(2×2) Capacity b/s/Hz
CASE 1		0.38	0.70	0.40	0.77
2.4	20				
CASE 2		0.22	0.41	0.23	0.42
2.4	40				
CASE 3		0.30	0.55	0.31	0.61
5	20				
CASE 4		0.17	0.31	0.17	0.33
5	40				

From Figure 4-4 and Table 4-3 we can notice that the range of the MIMO system is always greater than that of the SIMO system, but the SIMO system captures a significant part of the range improvement relative to the SISO reference system. Moreover, In figure 4-4(a) for example, when operating at a capacity of 1 bits/sec/Hz we have ranges of 3600 meters, 3700meters 4400 meters, and 4450 meters respectively, for SISO, MISO, SIMO and MIMO.

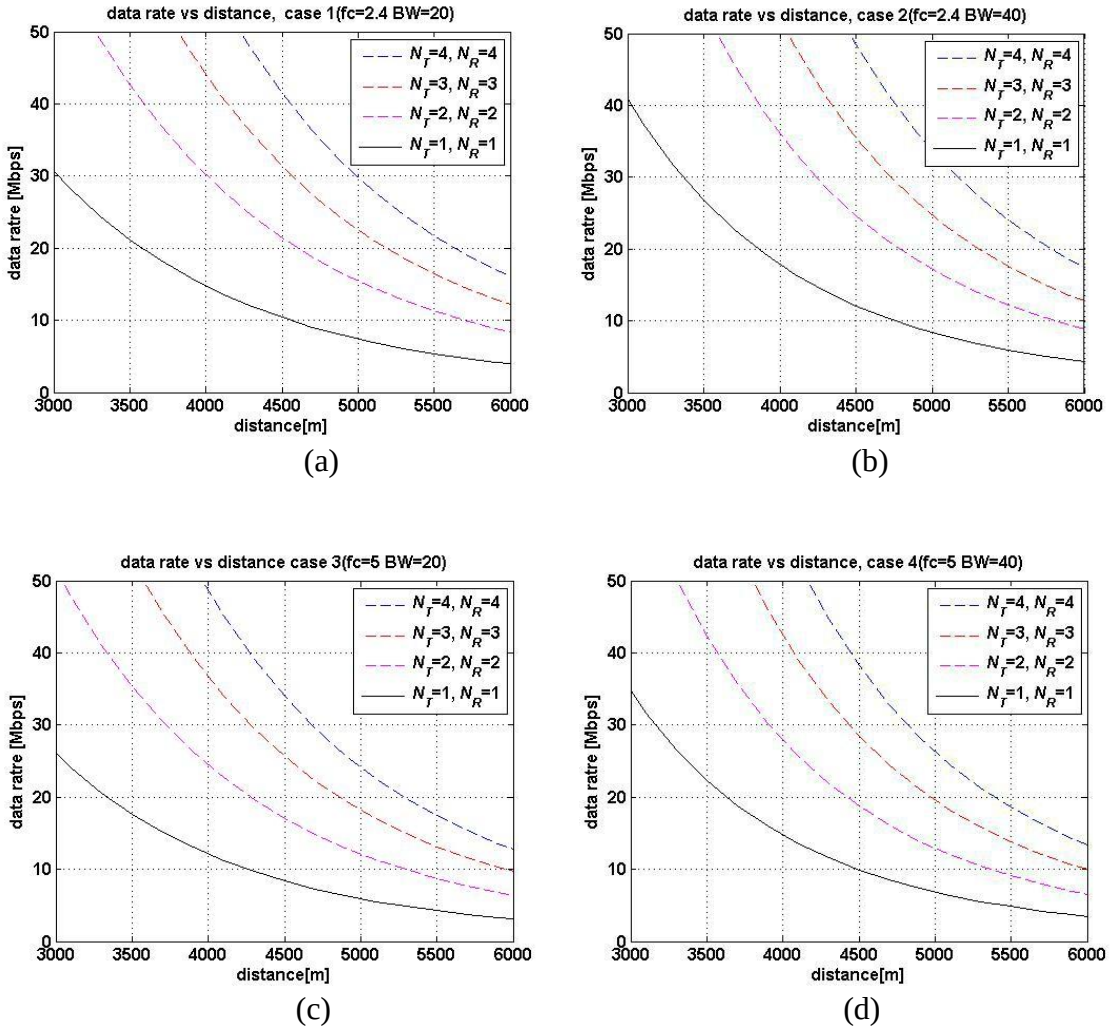


Figure 4-5: Data Rate vs. Distance for SISO and MIMO Antenna System for a) Case 1 b) Case 2 c) Case 3 d) Case 4

Figure 4-5 illustrate the variations of data rate with increasing distances for a single antenna system, and multiple antenna systems, we can notice the variation with the four cases of SNR values that was mentioned in the section above. We compared the data rate values at 5Km distance, and the result is shown in table 4-4 below.

Table 4-4: data rate values for SISO and MIMO systems at 5 km

Fc (GHz)	BW (MHz)	SISO(1×1) Data Rate Mbps	MIMO(2×2) Data Rate Mbps	MIMO(3×3) Data Rate Mbps	MIMO(4×4) Data Rate Mbps
CASE 1		8	15	23	30
2.4	20				
CASE 2		8	17	25	34
2.4	40				
CASE 3		6	12	18	24
5	20				
CASE 4		7	13	20	26
5	40				

From Figure 4-5 and Table 4-4 we can observe that the data rate is descending clearly with increasing the distance. Moreover, the highest values of data rate can be obtained by using the parameter in Case 2.