

Project	IEEE 802.16 Broadband Wireless Access Working Group < http://ieee802.org/16 >	
Title	Coverage/Capacity simulations for OFDMA PHY in with ITU-T channel model	
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Re:	Call for Comments: Editor's Draft Consolidation of IEEE 802.16/802.16a/802.16c – (802.16d-03/13)	
Abstract	OFDMA PHY performance and coverage simulations	
Purpose	Demonstrate performance of the OFDMA PHY in real coverage scenarios	
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Coverage/Capacity simulations for OFDMA PHY with ITU-T channel model

1 Simulated system

Coverage simulations have been prepared using the channel ITU-R recommendation M.1225 [1]. The scenario analyzed is for the channel ITU-B, which presents more severe conditions than its ITU-A counterpart, and which accounts to about 50% of the SS in the cell according to the model.

All simulations were done for an OFDMA system with 2K FFT and 32 sub-channels. The mobile station transmit power is limited to 20dBm. To maintain bi-directional communication the base station transmit power has been set to the mobile transmit power plus the OFDMA concentration gain. The OFDMA concentration gain is up to 15dB in this case, and therefore the BS transmission power has been set at. Some of the simulations include use of two antennas STC that can be achieved either by using the STC option, or by maximal-ratio-combining (MRC) at the receiver. The results therefore apply for the downlink channel, or for a single OFDMA uplink channel. Capacity calculations do not include overhead for preambles, guard intervals, etc.

The simulated system summary is

- 10MHz ITU-B channel at 2.4GHz
- Convolutional Turbo Coding FEC scheme with threshold BER of 10^{-5}
- The SS antenna is omni-directional with gain of 0dBi
- Various antennas were used for the BS. Beam-width of 60 degrees for six sectors scenario, 120 degrees for 3 sector scenario and 360 degrees for omni-directional scenario.
- Transmit power from the BS is 35dBm
- Receiver noise-figure of 4.5dB in the BS and 6.5dB in the UT

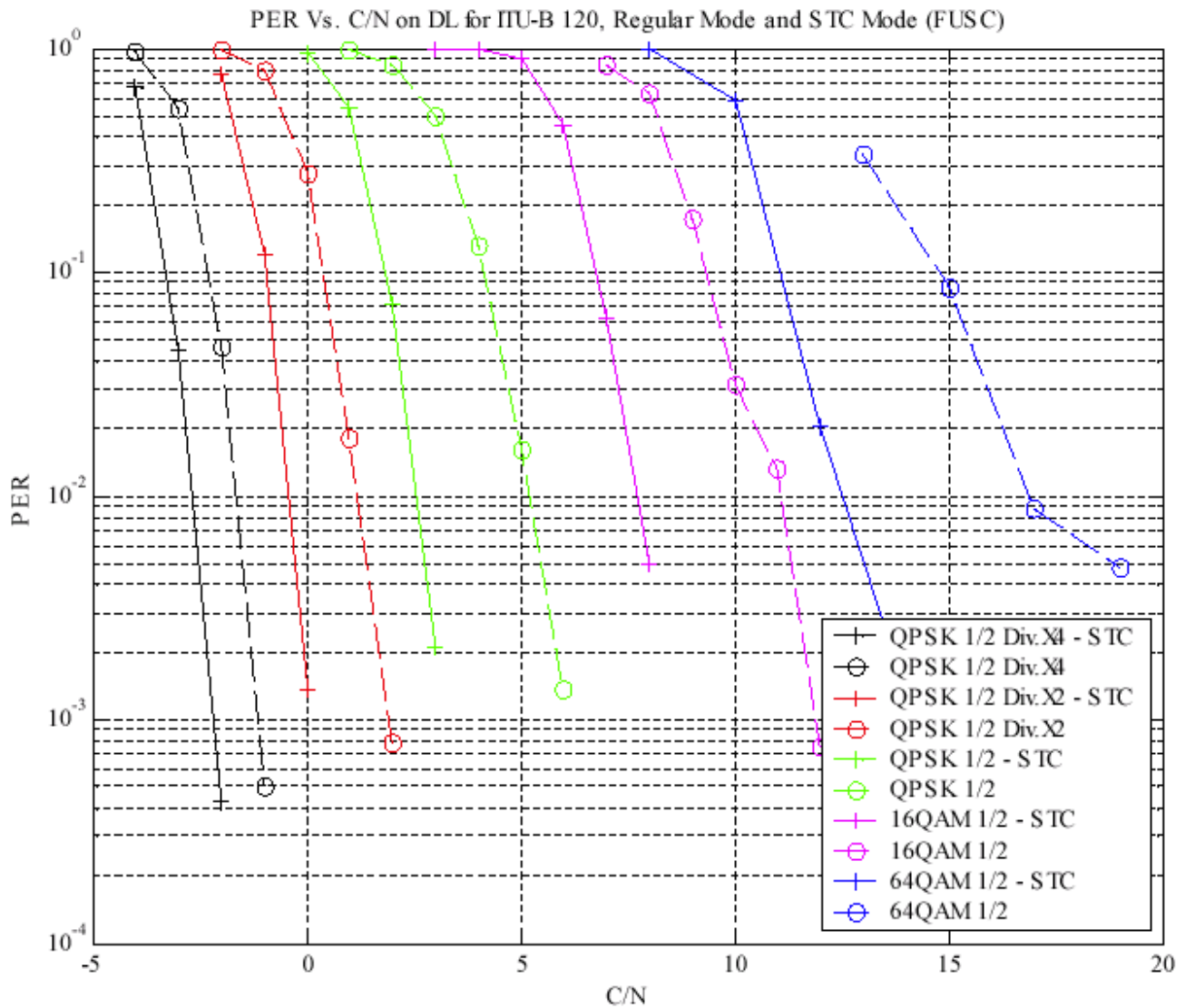
2 PHY performance graphs

The PHY performance is based on simulation results for FUSC and PUSC schemes. In both schemes ITU-A and ITU-B channels were simulated at 120/180 Km/h. The channel parameters for ITU-A and ITU-B are:

- ITU-A – 6 taps [0 0.31 0.71 1.09 1.73 2.51] μ sec
- ITU-B – 6 Taps [0 0.3 8.9 12.9 17.1 20] μ sec

Several modulation and coding combinations were simulated. Curves with Diversity X4 simulate a 4 times repetition of the QPSK rate $\frac{1}{2}$ transmission. Curves with Diversity X2 simulate a 2 times repetition of the QPSK rate $\frac{1}{2}$ transmission. All simulations include a residual frequency deviation of 1% of the CS. Coding block size is set to 144 bits for QPSK and 64QAM and to 96 bits for 16QAM.

The graphs legend includes the modulation/coding-rate/diversity details.



3 Some explanations about the coverage simulation

The simulation works by defining 19 BS and their sectors, and assigning a frequency sub-channel to each sector according to the frequency reuse factor. For each grid point in the center cell, a Monte-Carlo S/(N+I) calculation is performed. The path loss is calculated using the formula $PL(d) = 37 \cdot \log_{10}(d) + 20 \cdot \log_{10}(f) + 43.58$, where $f = 2400\text{MHz}$ and d is in Km.

Log-normal slow fading with $\sigma = 10$ is, such that the fading is 100% correlated between sectors of the same BS, and 50% correlated between BS. For each point the sector with the best S/(N+I) is selected and an independent Rayleigh distributed random path-loss component is added to simulate fast fading. After this, S/(N+I) is calculated and the appropriate bit/sec/Hz value is assigned according to the PHY performance graphs (including an additional 1dB of implementation loss).

4 Simulation Results

Scenario: Omni, reuse 1, ITU-B,120Km/H

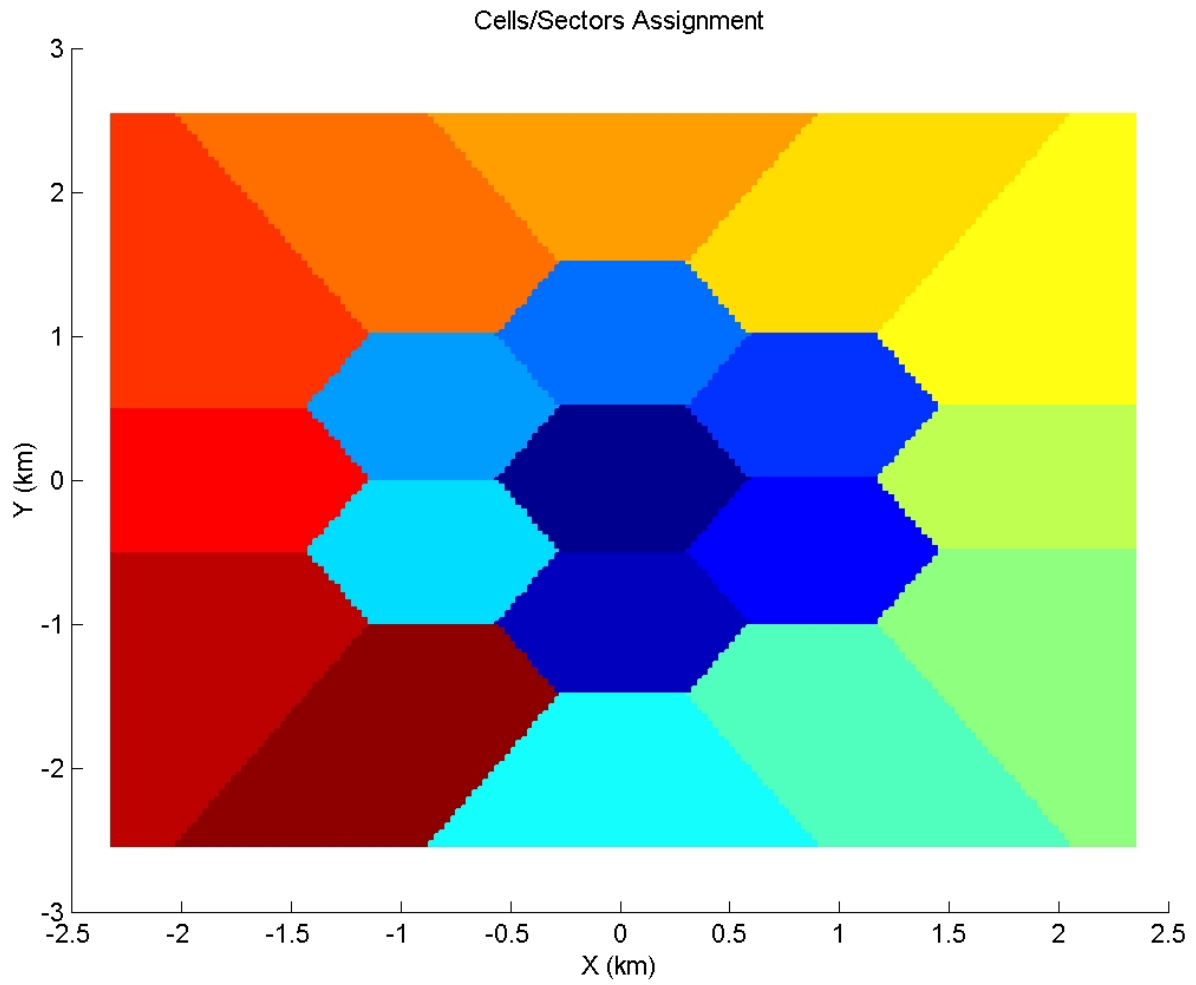


Figure 1: Cell/Sector Assignment - Omni, reuse 1, ITU-B,120Km/H

Coverage Statistics:

- Average DL throughput = 1.12 Bit/Sec/Hz per sector
- DL Coverage

- **FADE - 14.64%**
- QPSK, 1/8 - 16.17%
- QPSK, 1/4 - 22.12%
- QPSK, 1/2 - 13.60%
- QPSK, 3/4 - 8.42%
- 16QAM, 1/2 - 12.05%
- 16QAM, 3/4 - 4.97%
- 64QAM, 2/3 - 8.03%

- Average UL throughput = 0.79 Bit/Sec/Hz per sector
- UL Coverage

- **FADE - 12.23%**
- QPSK, 1/8 - 13.75%
- QPSK, 1/4 - 28.99%
- QPSK, 1/2 - 23.51%
- QPSK, 3/4 - 12.75%
- 16QAM, 1/2 - 8.35%
- 16QAM, 3/4 - 0.42%
- 64QAM, 2/3 - 0.01%

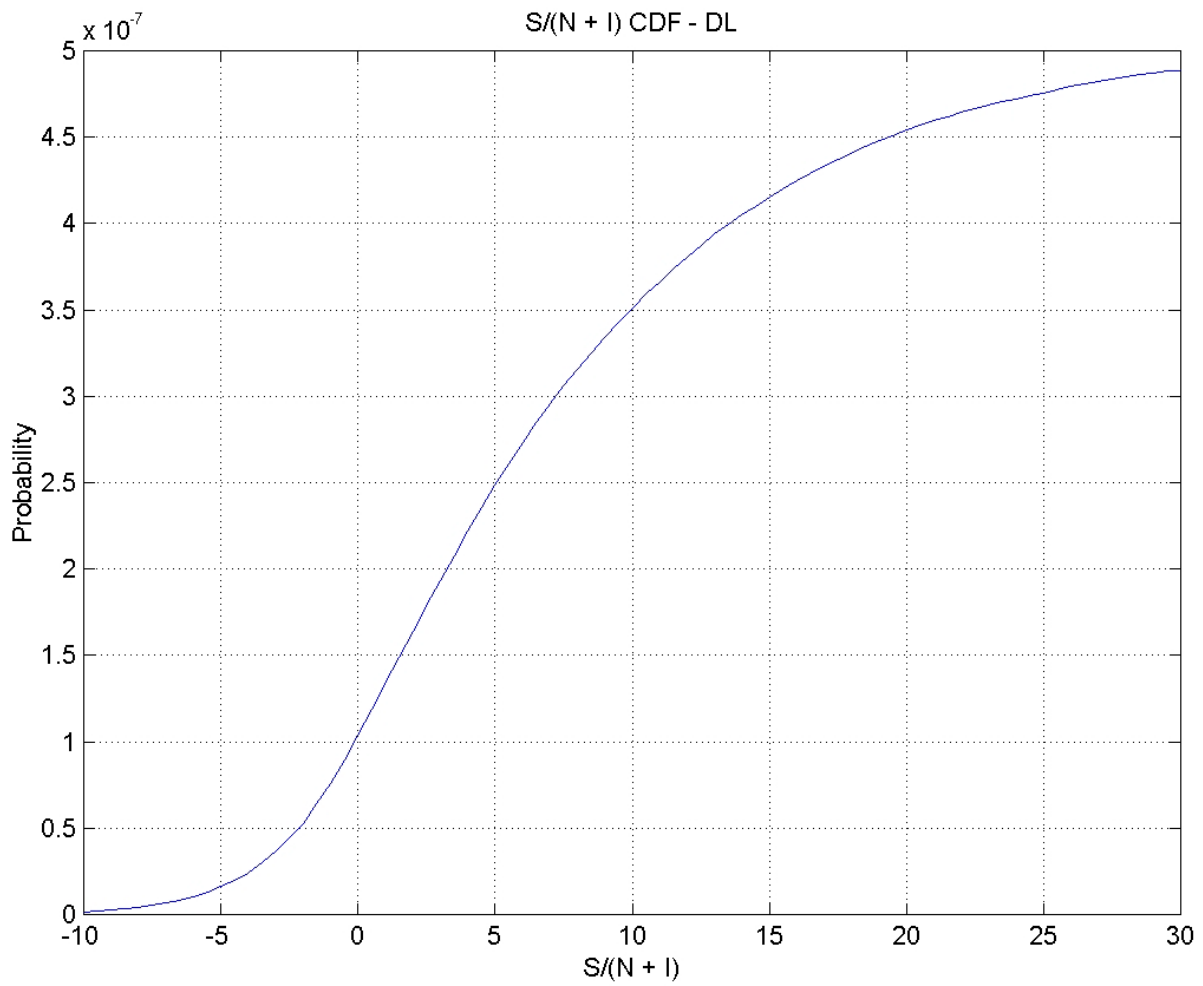


Figure 2: S/(N+I) Cumulative Distribution Function (CDF) in the downlink - Omni, reuse 1, ITU-B,120Km/H

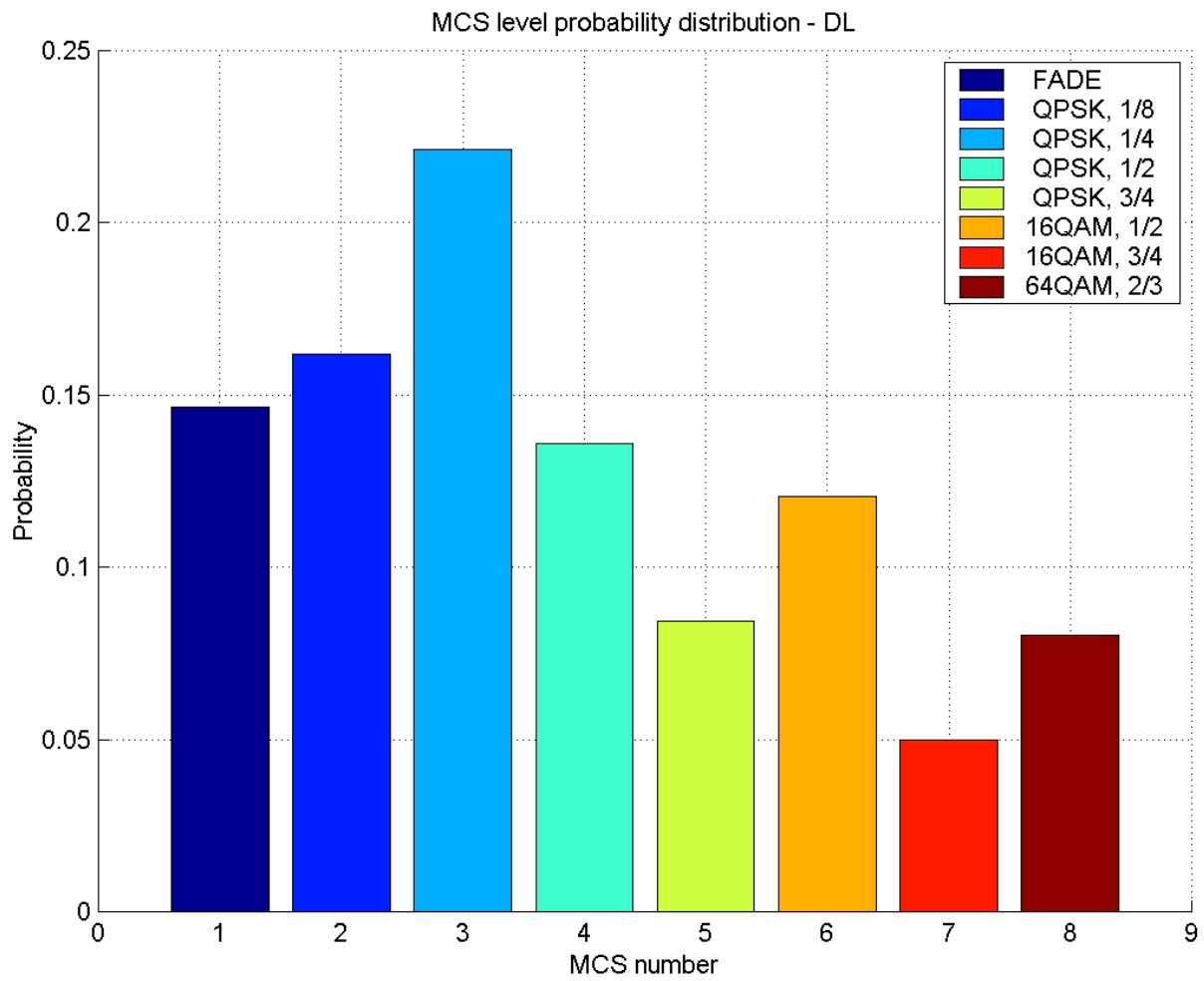


Figure 3: Modulation/Coding distribution in the downlink - Omni, reuse 1, ITU-B,120Km/H

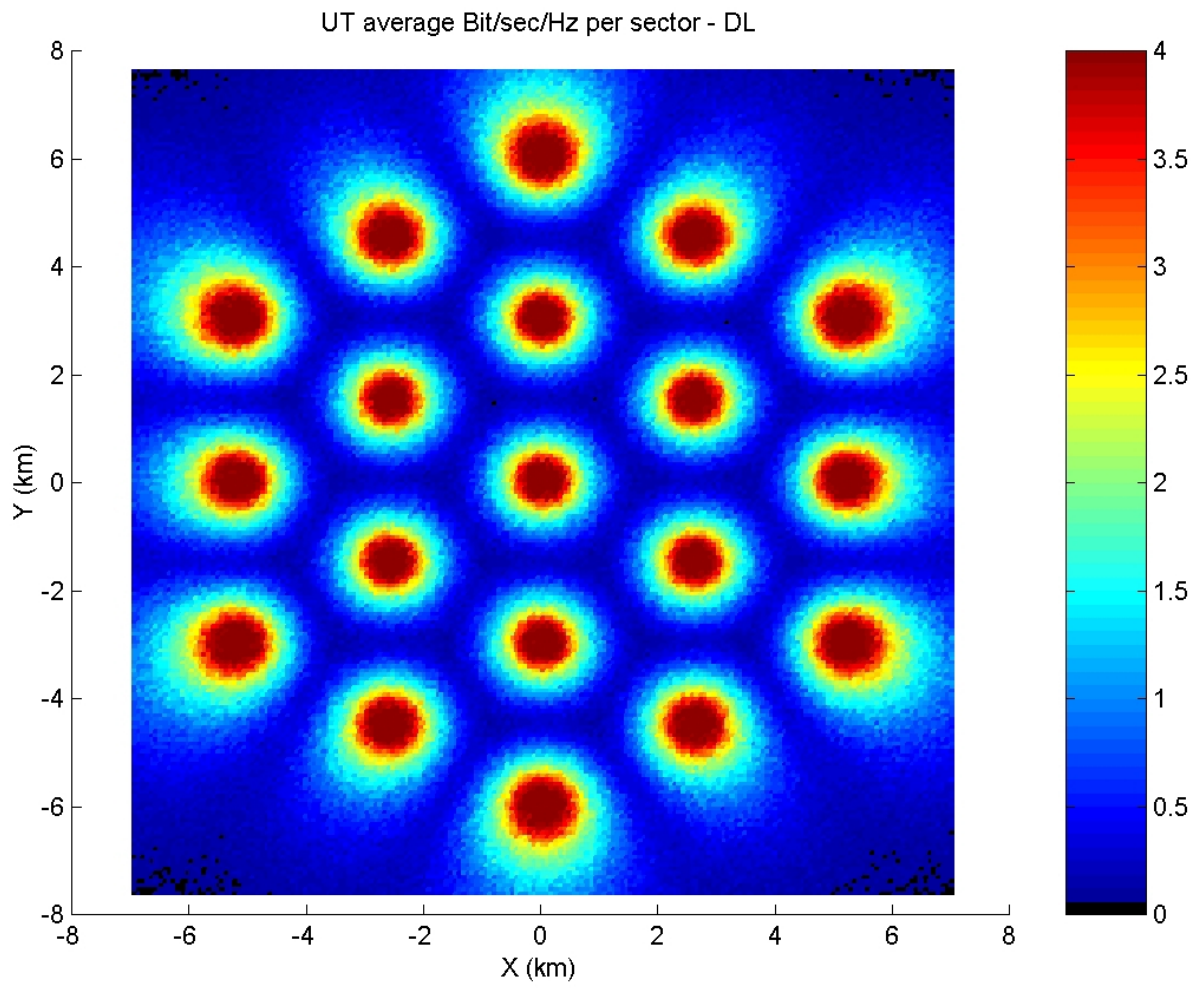


Figure 4: Average bit/sec/Hz per sector in the downlink - Omni, reuse 1, ITU-B,120Km/H

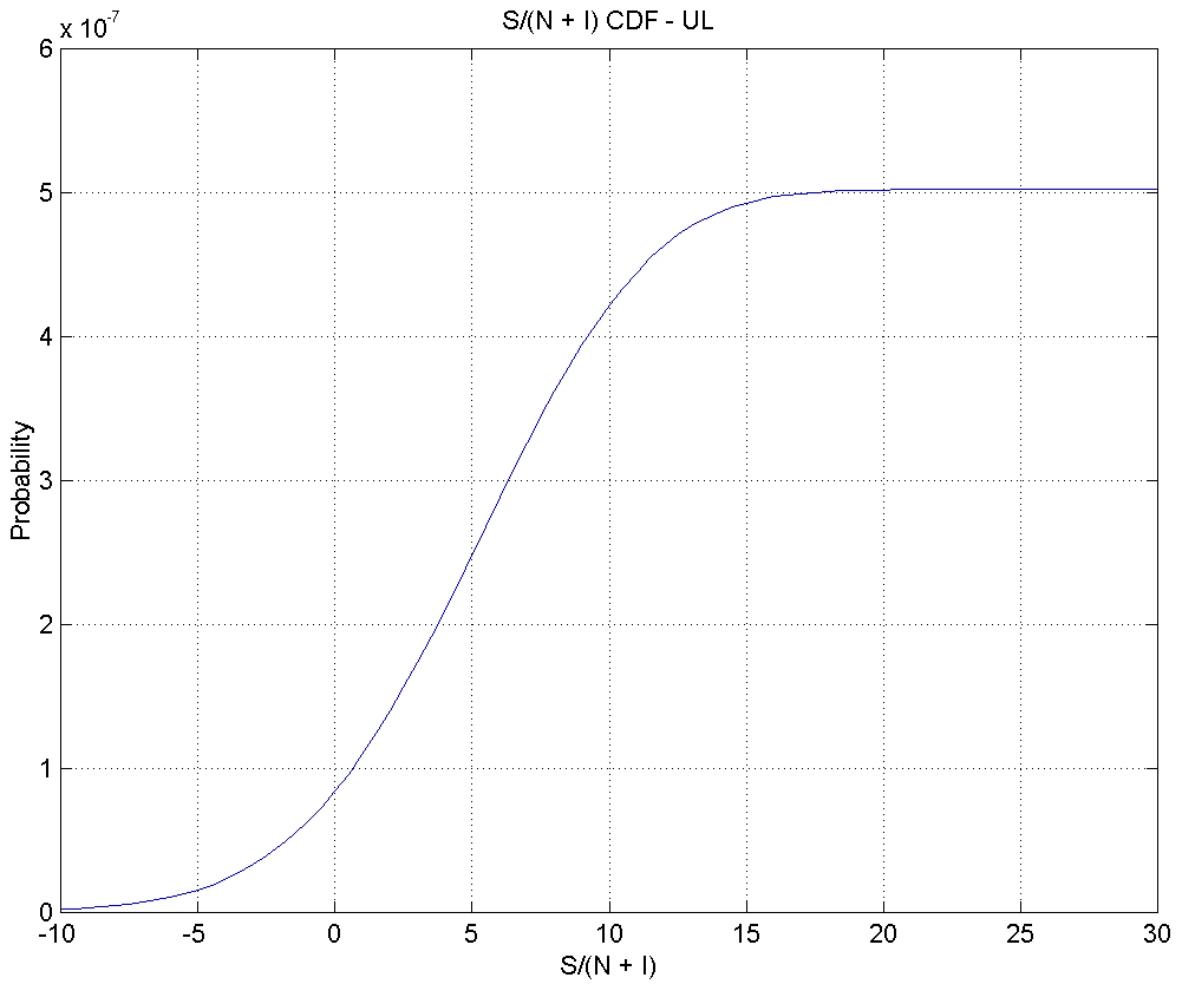


Figure 5: S/(N+I) Cumulative Distribution Function (CDF) in the uplink - Omni, reuse 1, ITU-B,120Km/H

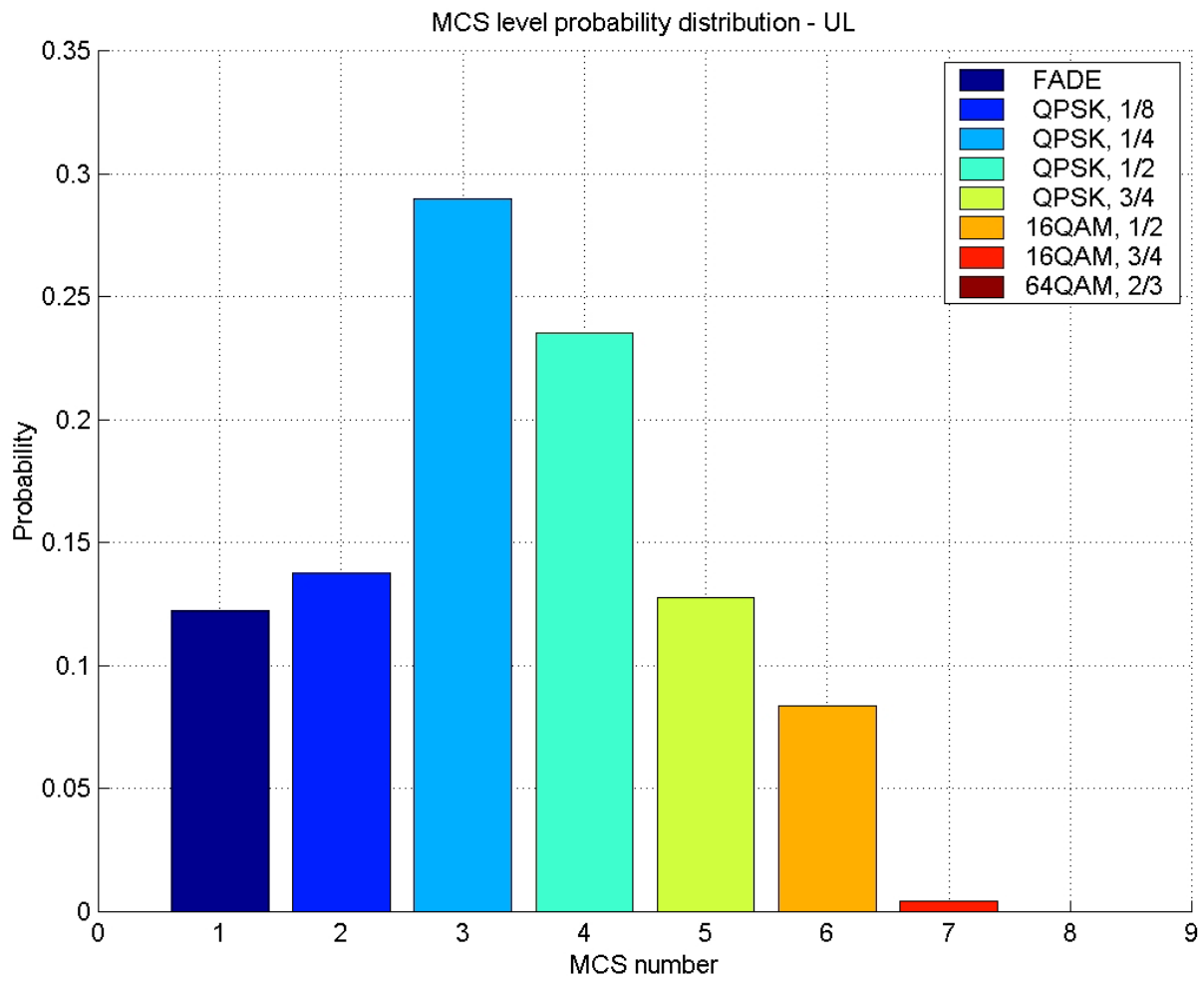


Figure 6: Modulation/Coding distribution in the uplink - Omni, reuse 1, ITU-B,120Km/H

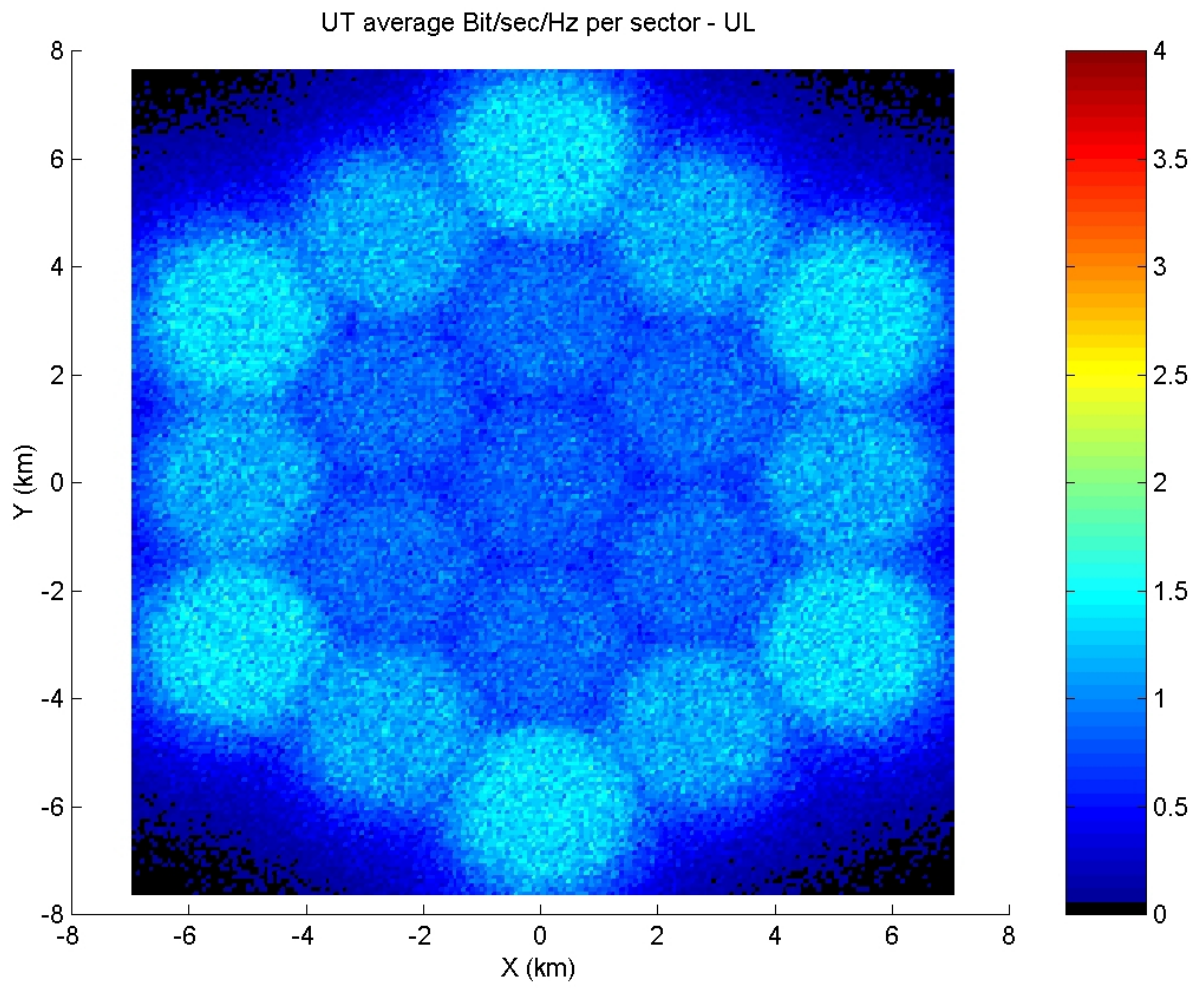


Figure 7: Average bit/sec/Hz per sector in the uplink - Omni, reuse 1, ITU-B,120Km/H

Scenario: 3 sectors, reuse 1, ITU-B, 120Km/H

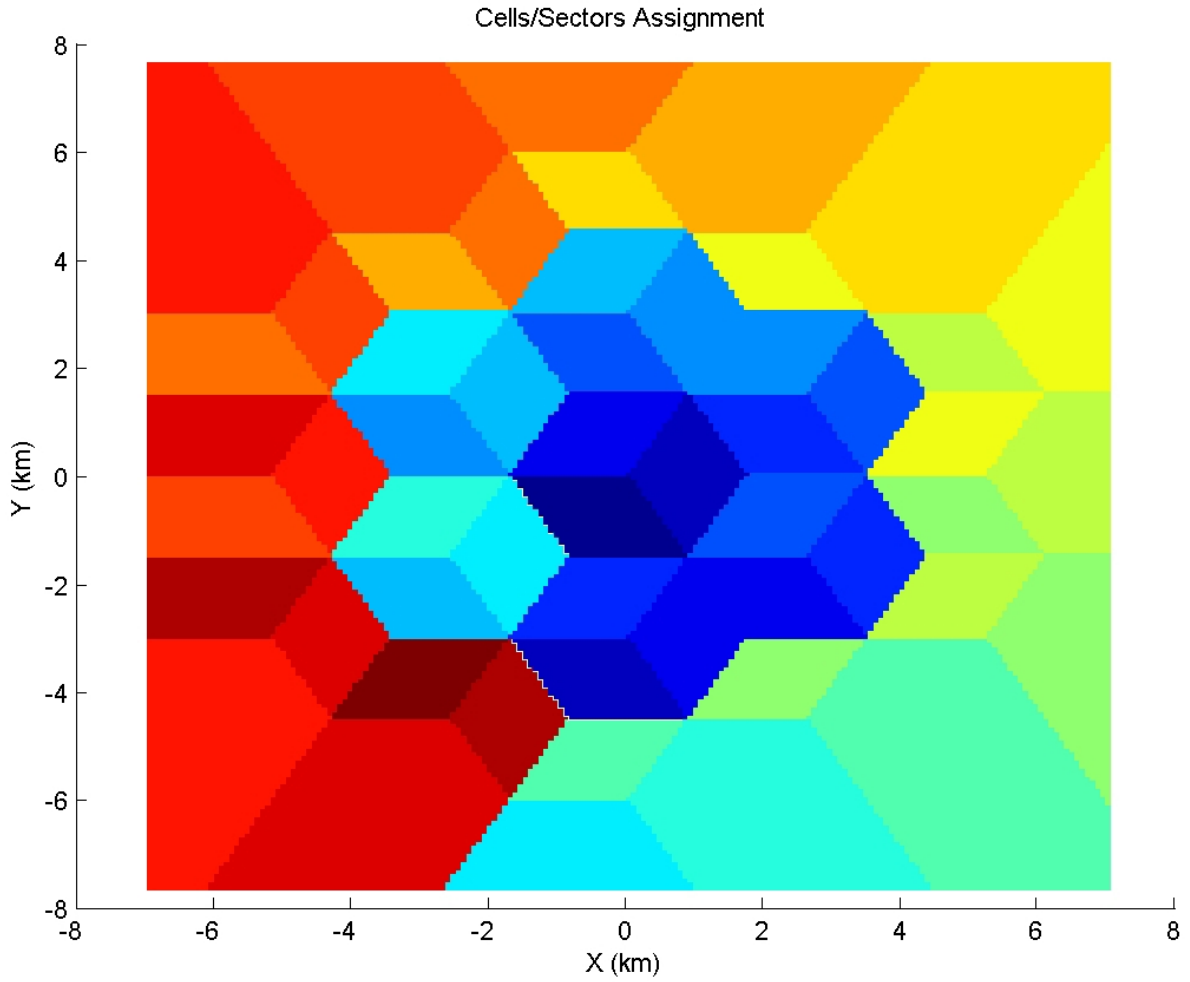


Figure 1: Cell/Sector Assignment - 3 sectors, reuse 1, ITU-B, 120Km/H

Coverage Statistics:

- Average DL throughput = 0.41 Bit/Sec/Hz per sector
- DL Coverage

- **FADE - 33.01%**
- QPSK, 1/8 - 22.99%
- QPSK, 1/4 - 25.19%
- QPSK, 1/2 - 12.09%
- QPSK, 3/4 - 5.22%
- 16QAM, 1/2 - 1.50%
- 16QAM, 3/4 - 0.00%
- 64QAM, 2/3 - 0.00%

- Average UL throughput = 0.38 Bit/Sec/Hz per sector
- UL Coverage

- **FADE - 37.00%**
- QPSK, 1/8 - 21.05%
- QPSK, 1/4 - 25.48%
- QPSK, 1/2 - 11.34%
- QPSK, 3/4 - 3.64%
- 16QAM, 1/2 - 1.47%
- 16QAM, 3/4 - 0.02%
- 64QAM, 2/3 - 0.00%

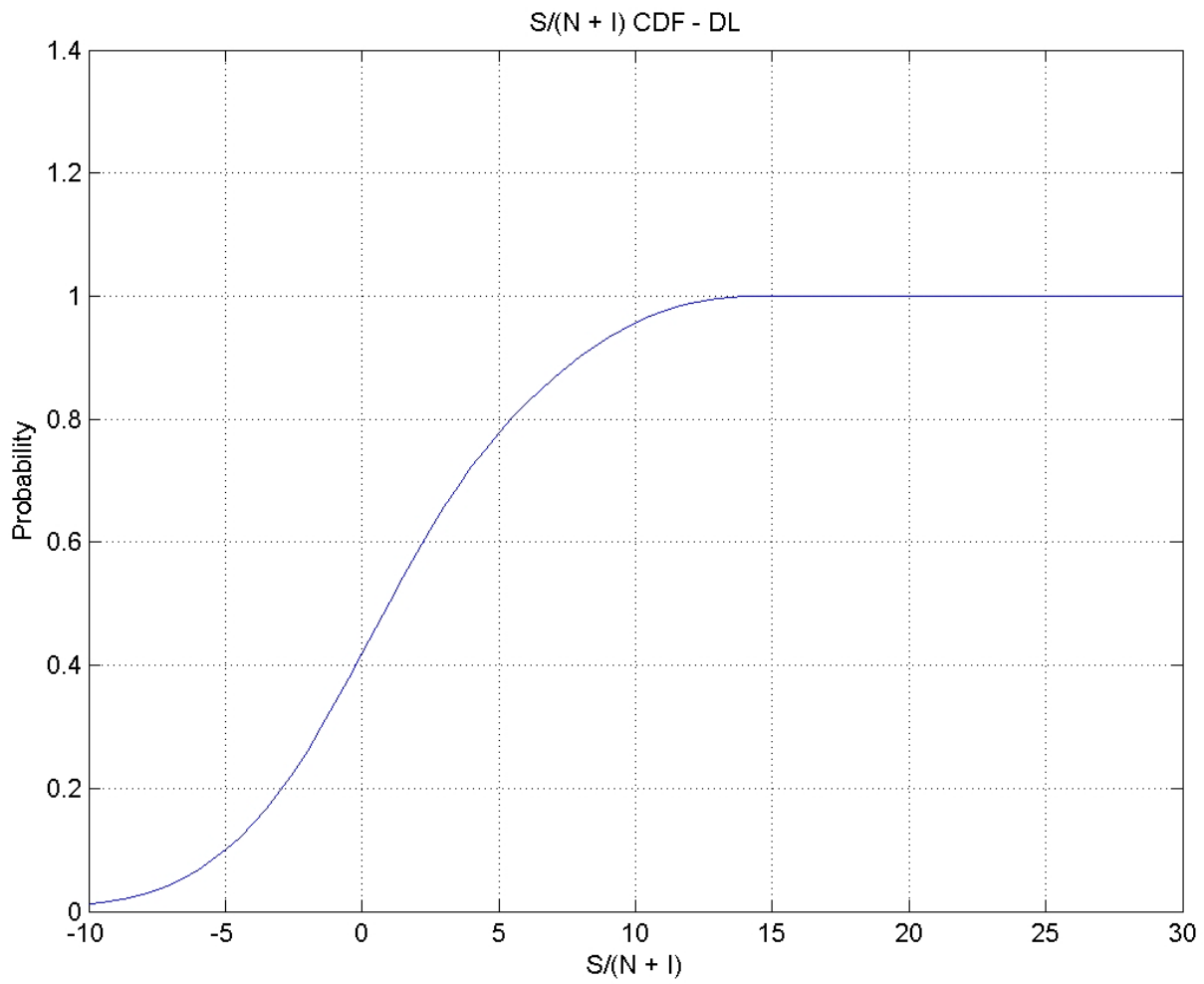


Figure 2: $S/(N+I)$ Cumulative Distribution Function (CDF) in the downlink - 3 sectors, reuse 1, ITU-B, 120Km/H

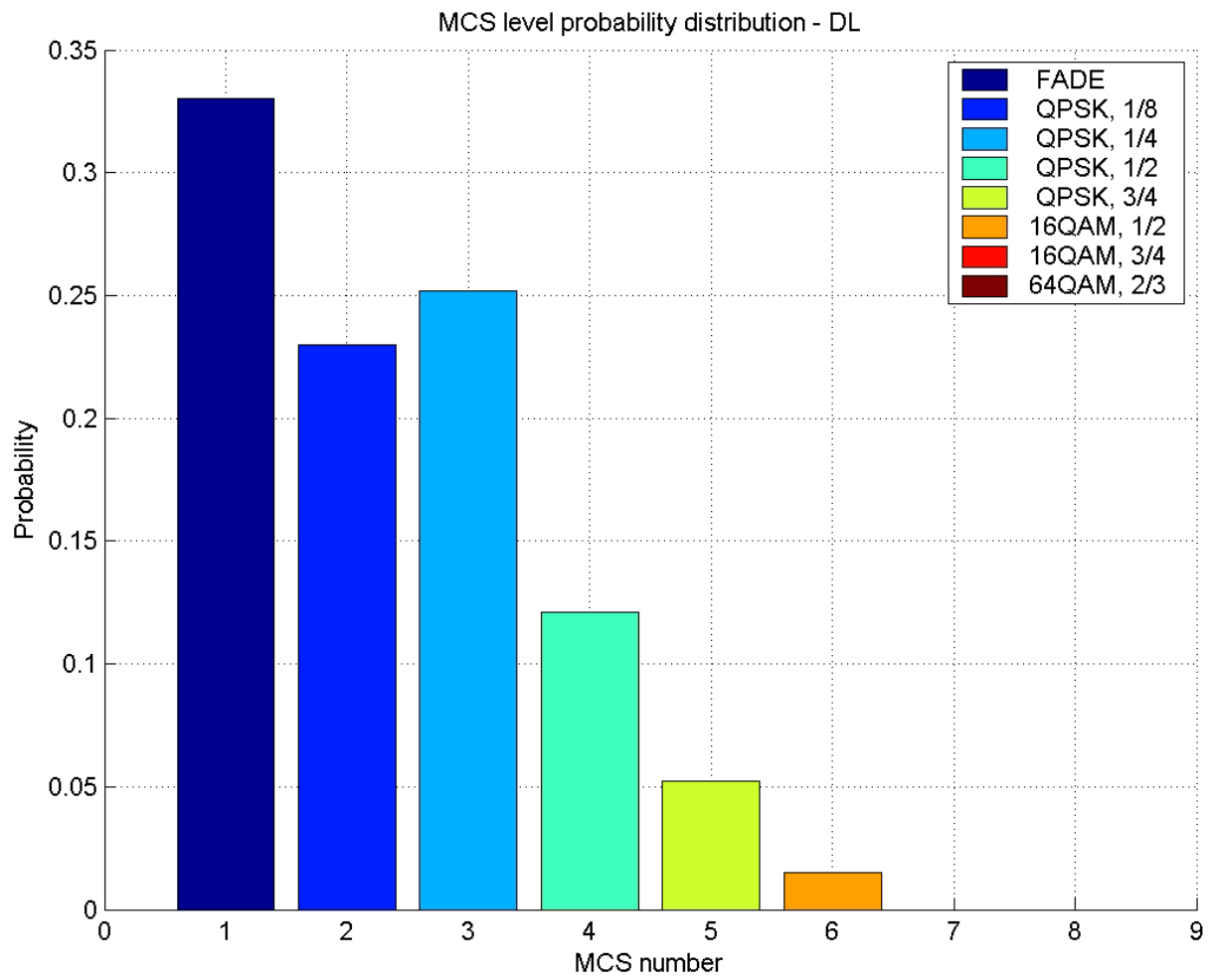


Figure 3: Modulation/Coding distribution in the downlink - 3 sectors, reuse 1, ITU-B, 120Km/H

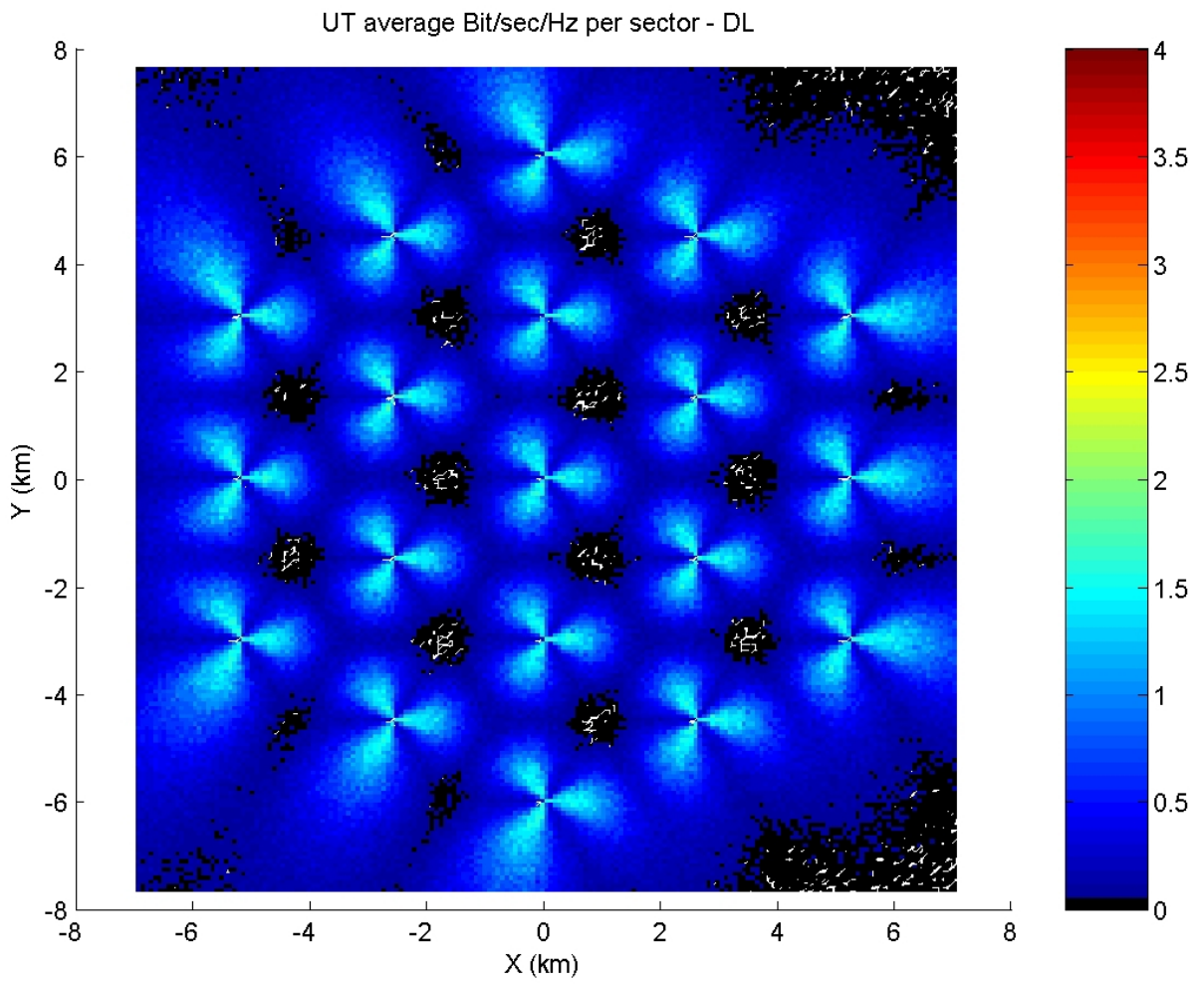


Figure 4: Average bit/sec/Hz per sector in the downlink - 3 sectors, reuse 1, ITU-B, 120Km/H

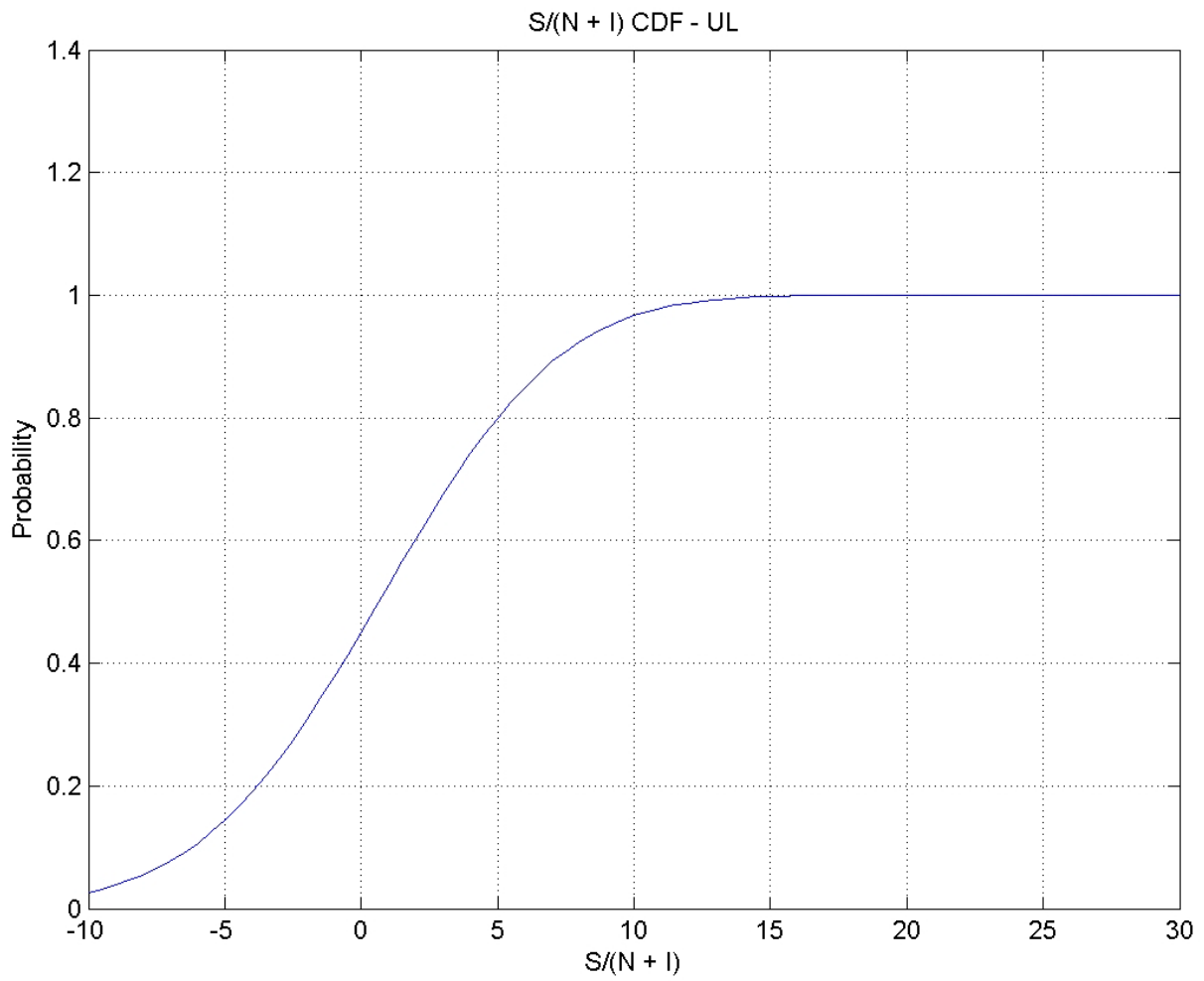


Figure 5: $S/(N+I)$ Cumulative Distribution Function (CDF) in the uplink - 3 sectors, reuse 1, ITU-B, 120Km/H

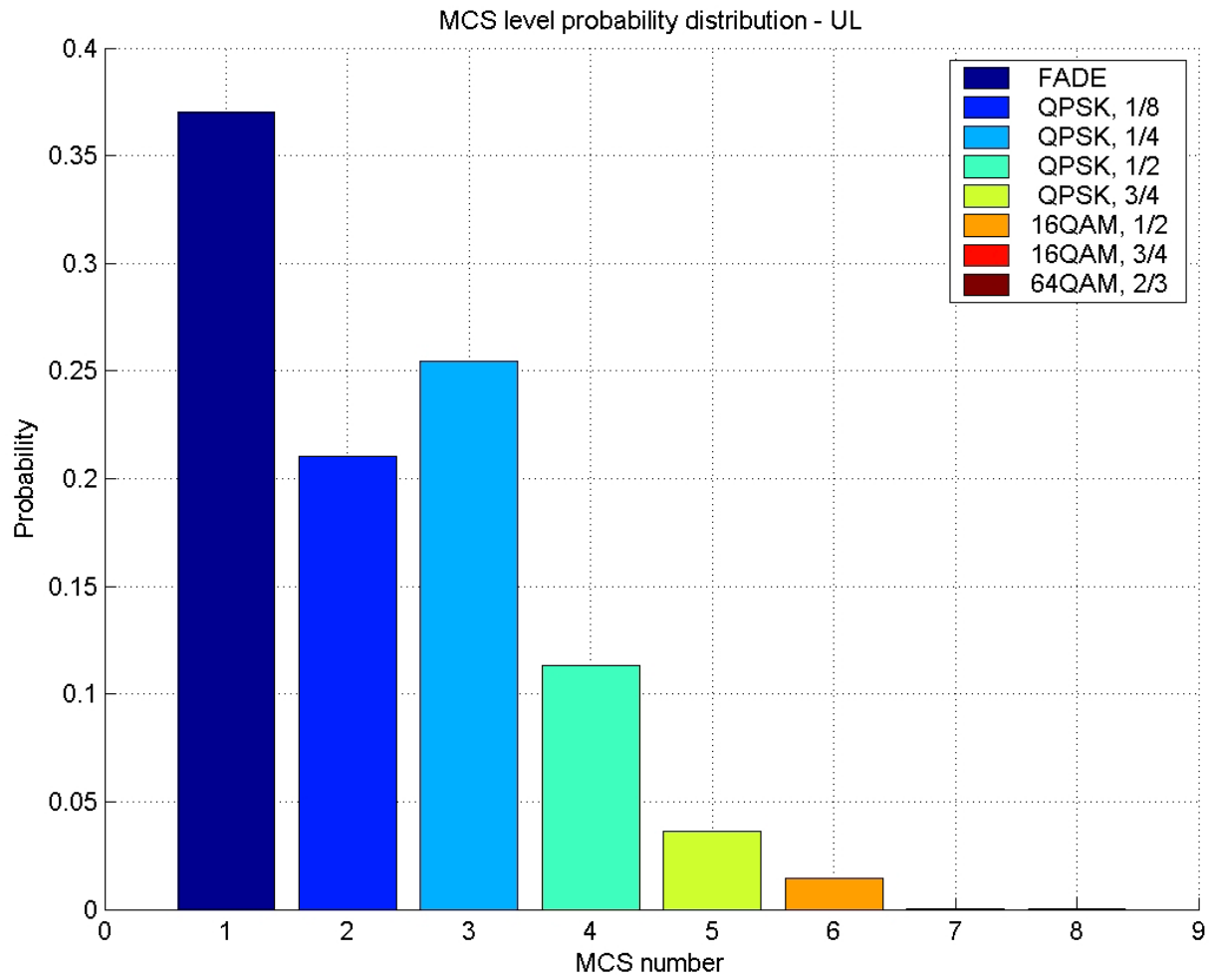


Figure 6: Modulation/Coding distribution in the uplink - 3 sectors, reuse 1, ITU-B, 120Km/H

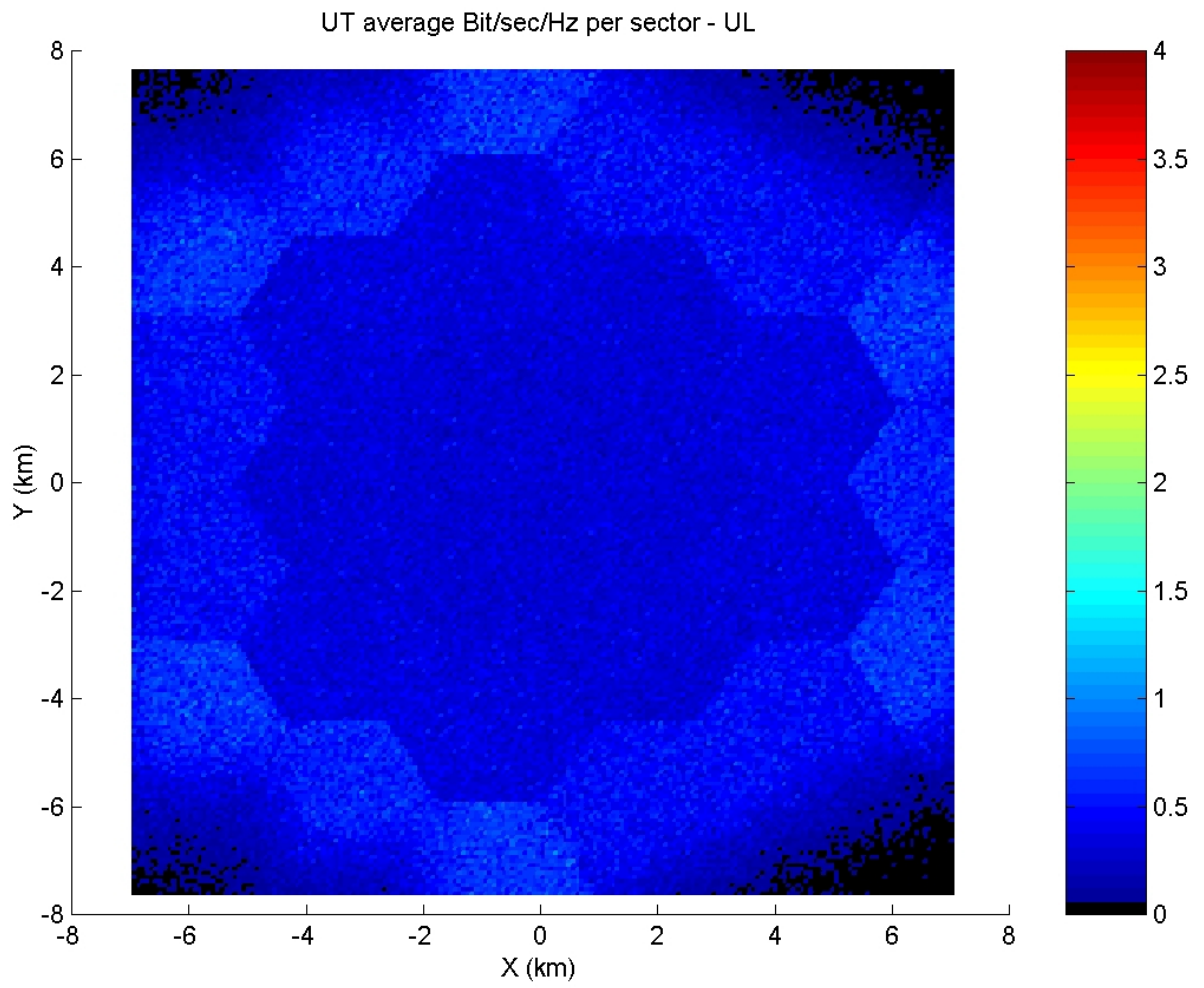


Figure 7: Average bit/sec/Hz per sector in the uplink - 3 Sectors, reuse 1, ITU-B,120Km/H

Scenario: 3 sectors, reuse 1/3, ITU-B, 120Km/H

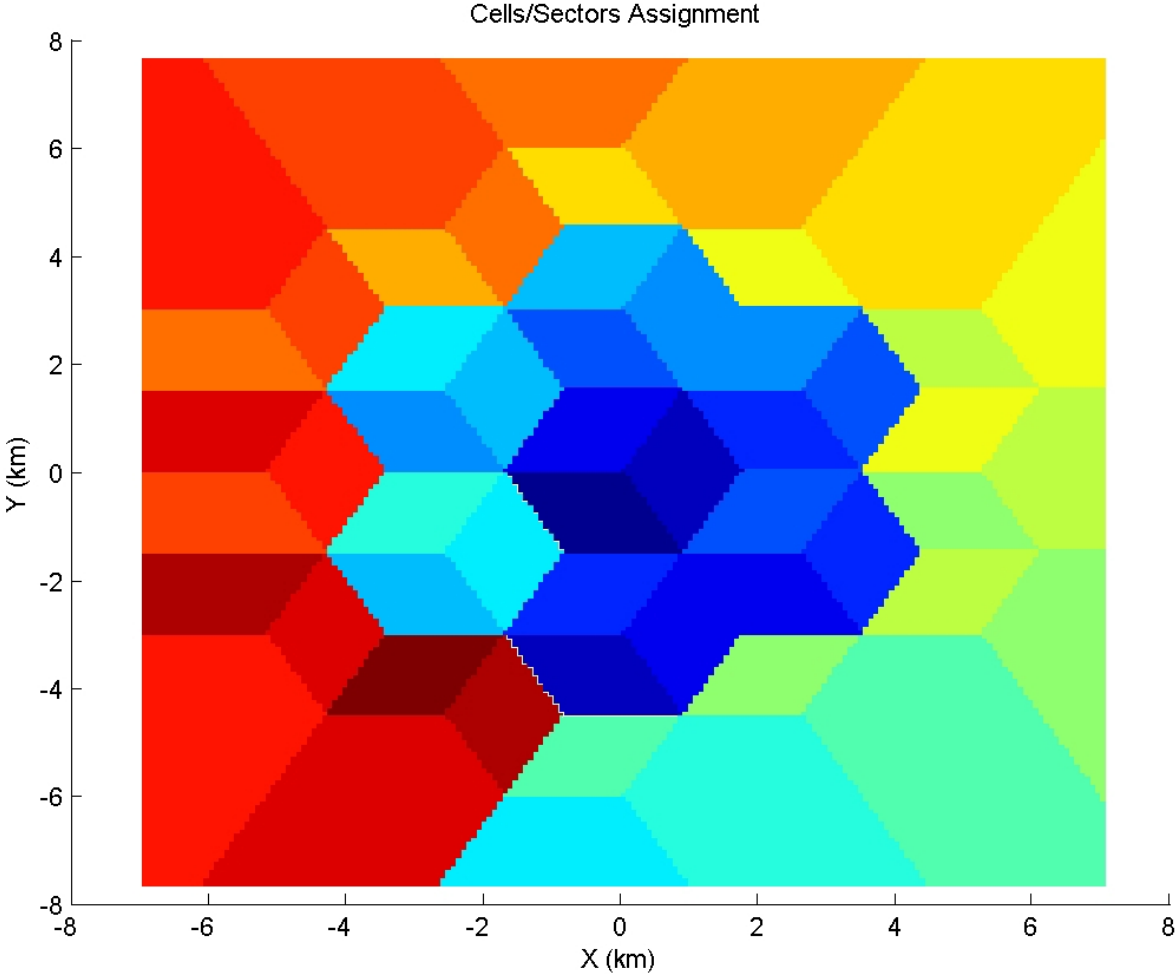


Figure 1: Cell/Sector Assignment - 3 sectors, reuse 1/3, ITU-B, 120Km/H

Coverage Statistics:

- Average DL throughput = 0.57 Bit/Sec/Hz per sector
- DL Coverage

- **FADE - 4.75%**
- QPSK, 1/8 - 7.06%
- QPSK, 1/4 - 16.34%
- QPSK, 1/2 - 15.30%
- QPSK, 3/4 - 12.14%
- 16QAM, 1/2 - 20.99%
- 16QAM, 3/4 - 9.31%
- 64QAM, 2/3 - 14.11%

- Average UL throughput = 0.49 Bit/Sec/Hz per sector
- UL Coverage

- **FADE - 1.92%**
- QPSK, 1/8 - 3.54%
- QPSK, 1/4 - 12.46%
- QPSK, 1/2 - 20.01%
- QPSK, 3/4 - 21.23%
- 16QAM, 1/2 - 34.33%
- 16QAM, 3/4 - 5.91%
- 64QAM, 2/3 - 0.59%

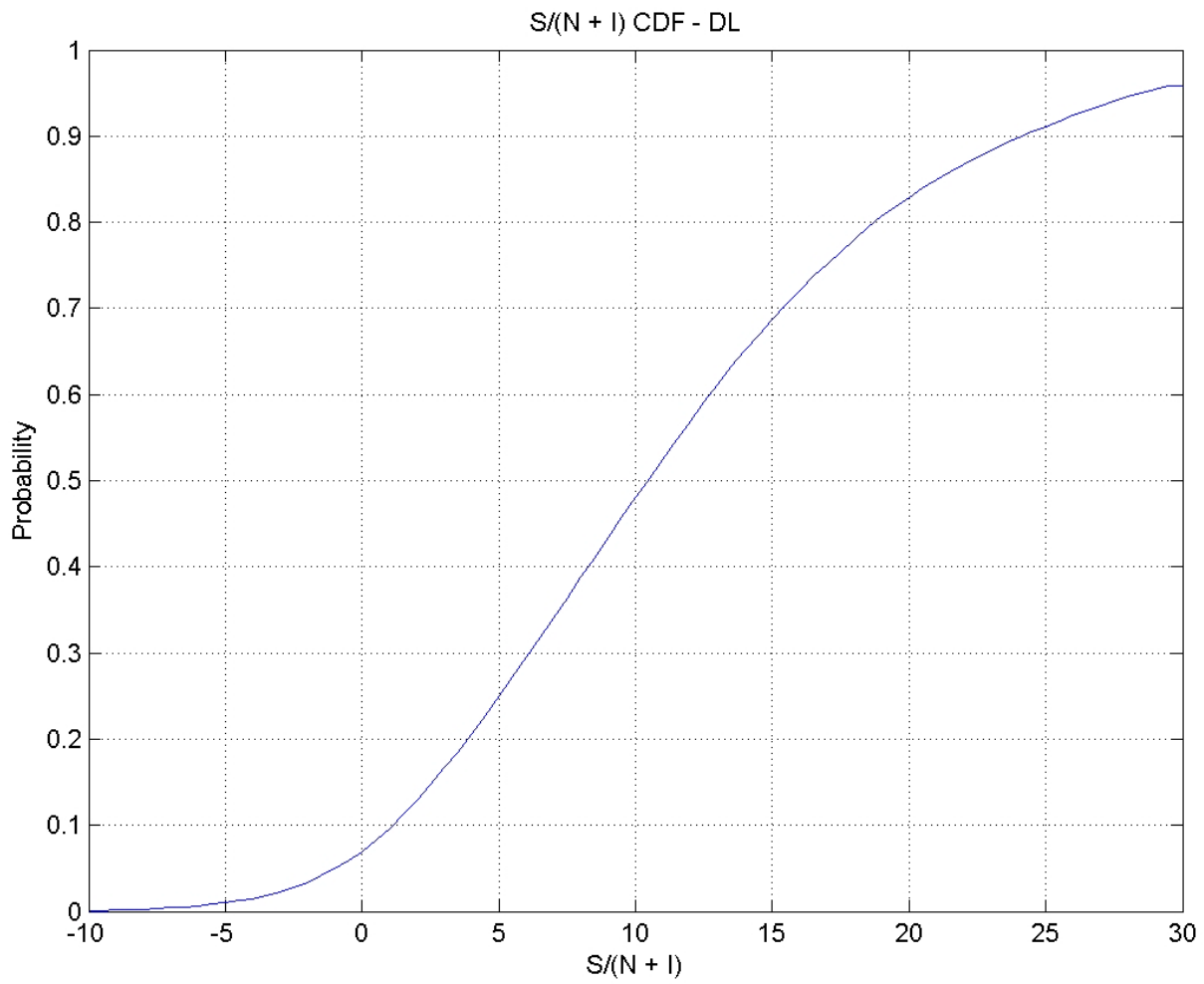


Figure 2: S/(N+I) Cumulative Distribution Function (CDF) in the downlink - 3 sectors, reuse 1/3, ITU-B, 120Km/H

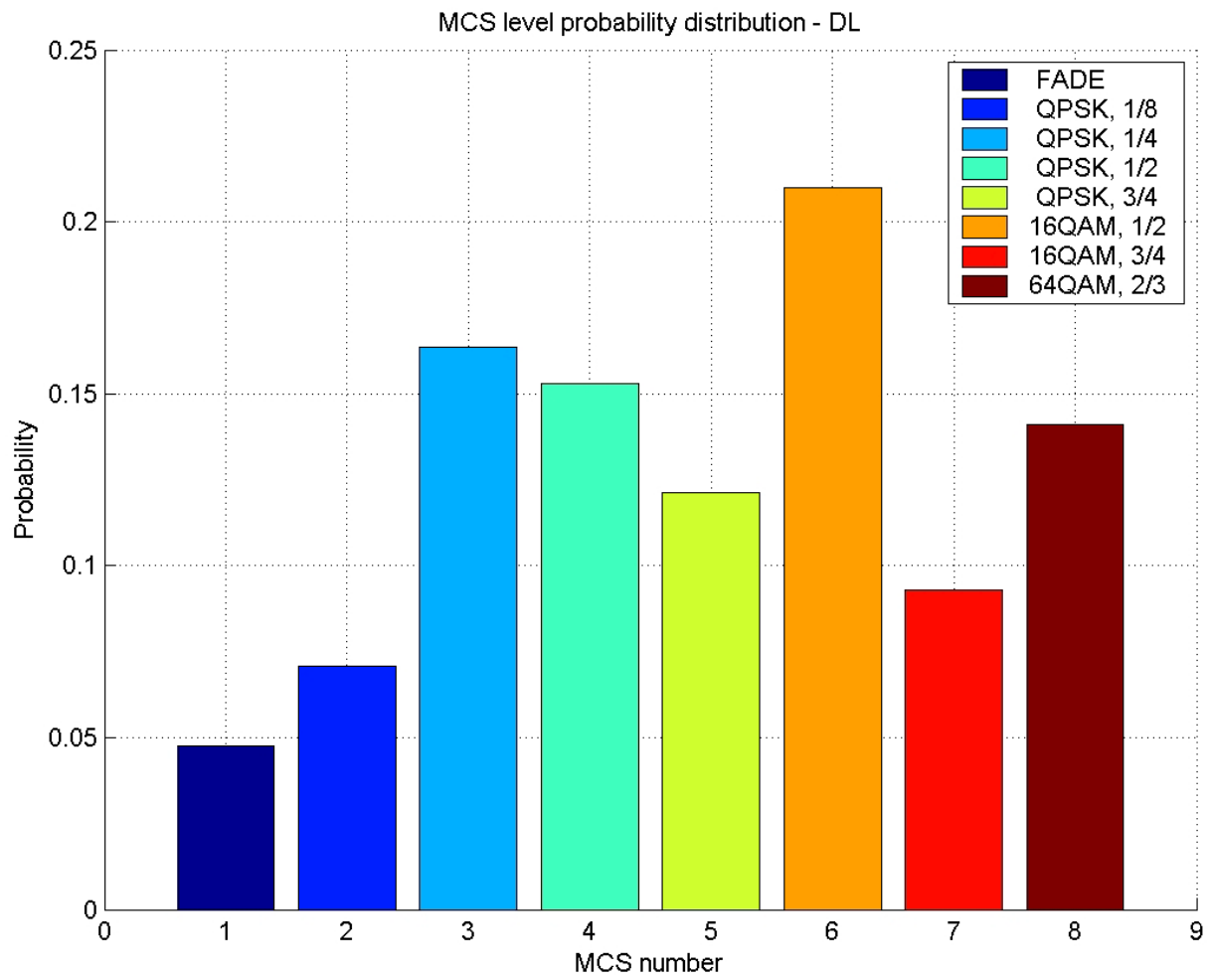


Figure 3: Modulation/Coding distribution in the downlink - 3 sectors, reuse 1/3, ITU-B, 120Km/H

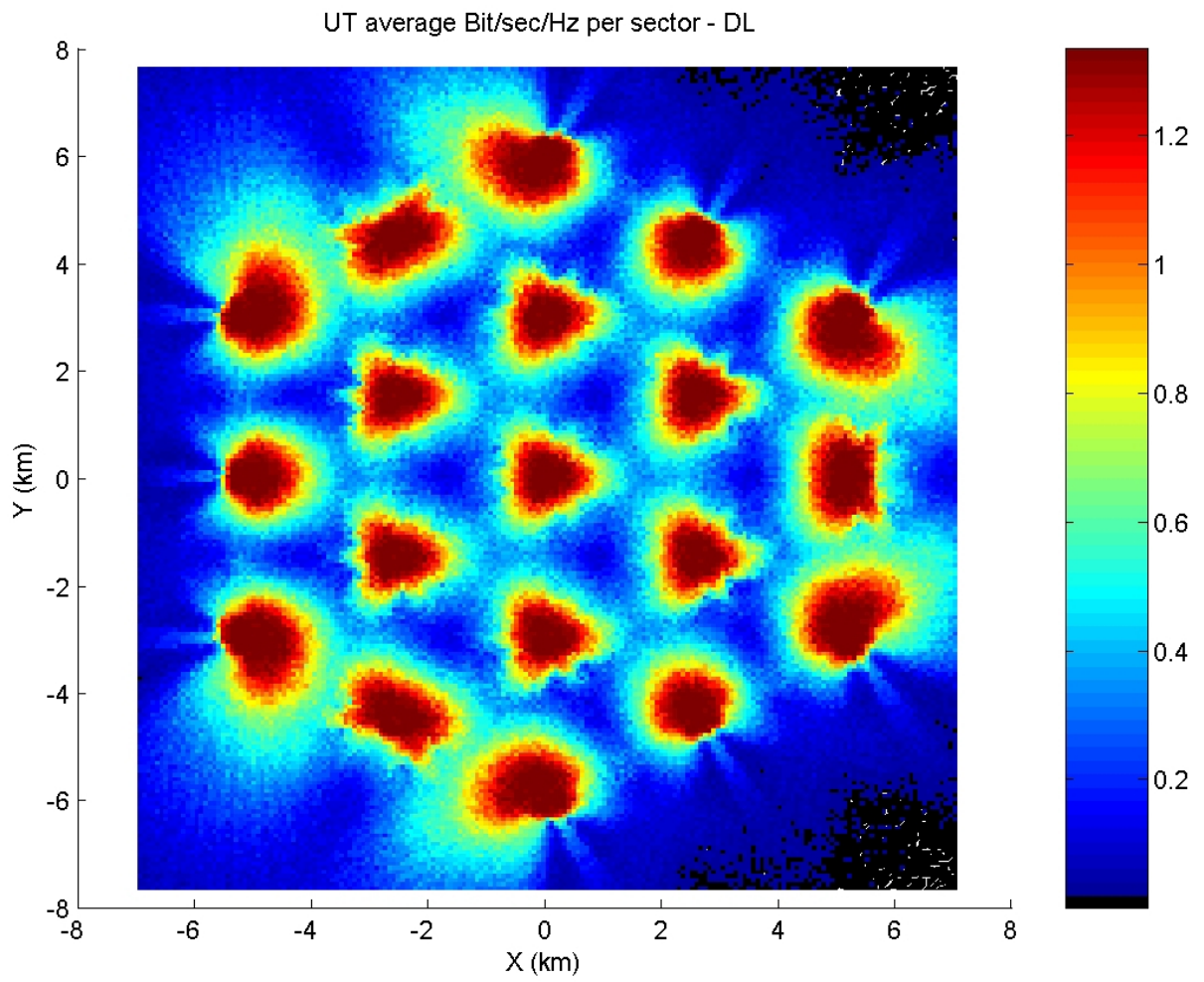


Figure 4: Average bit/sec/Hz per sector in the downlink - 3 sectors, reuse 1/3, ITU-B, 120Km/H

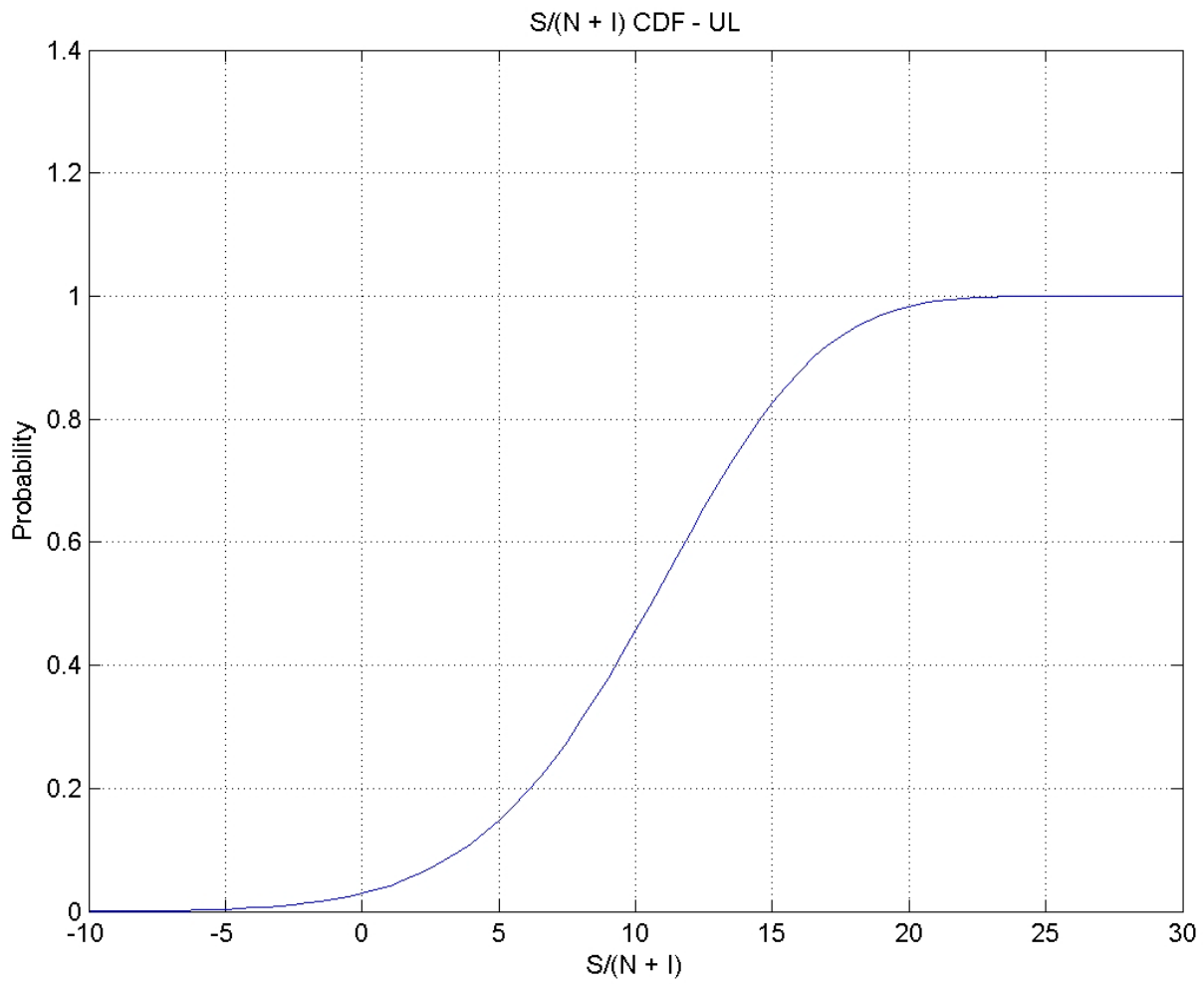


Figure 5: S/(N+I) Comulative Distribution Function (CDF) in the uplink - 3 sectors, reuse 1/3, ITU-B, 120Km/H

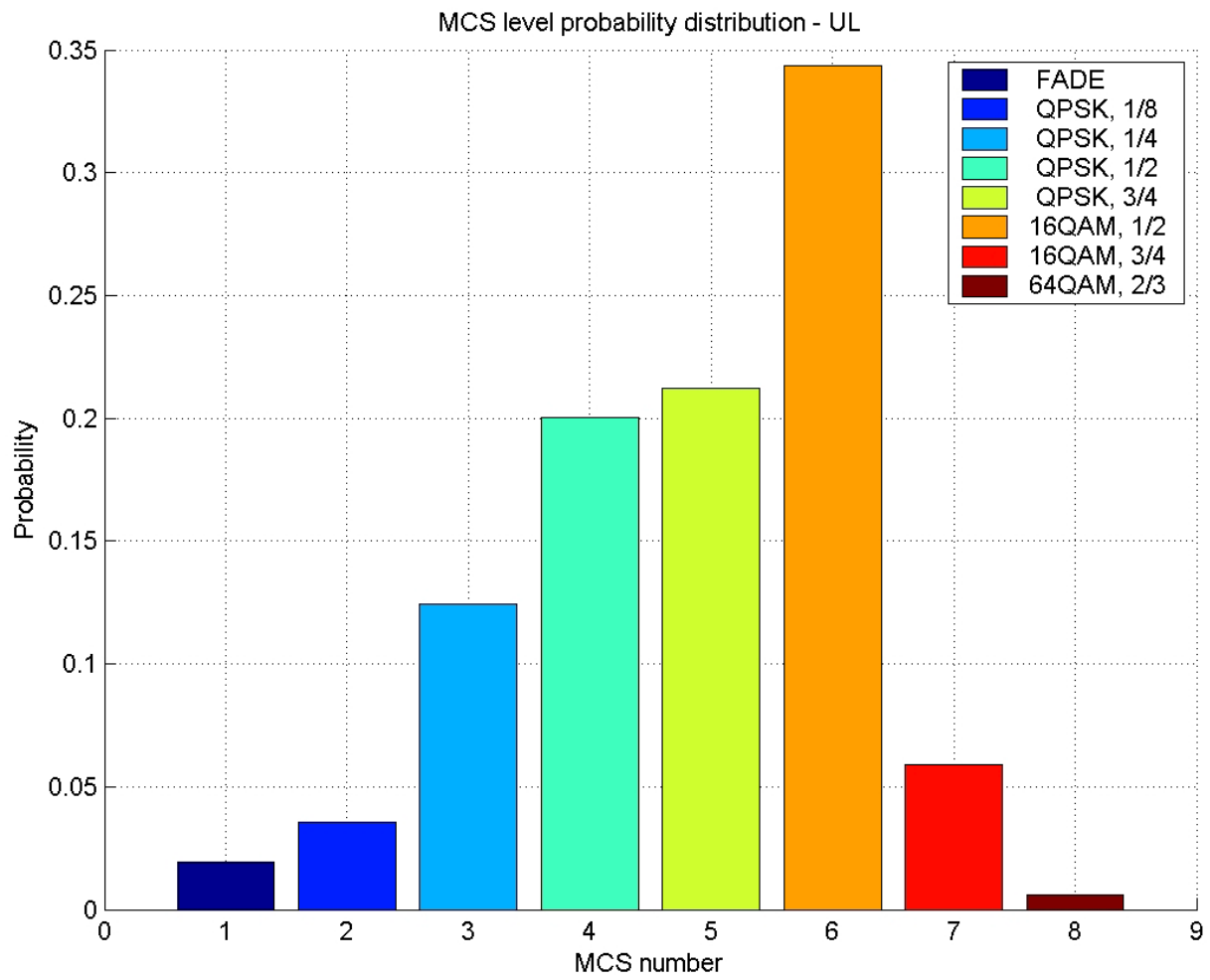


Figure 6: Modulation/Coding distribution in the uplink - 3 sectors, reuse 1/3, ITU-B, 120Km/H

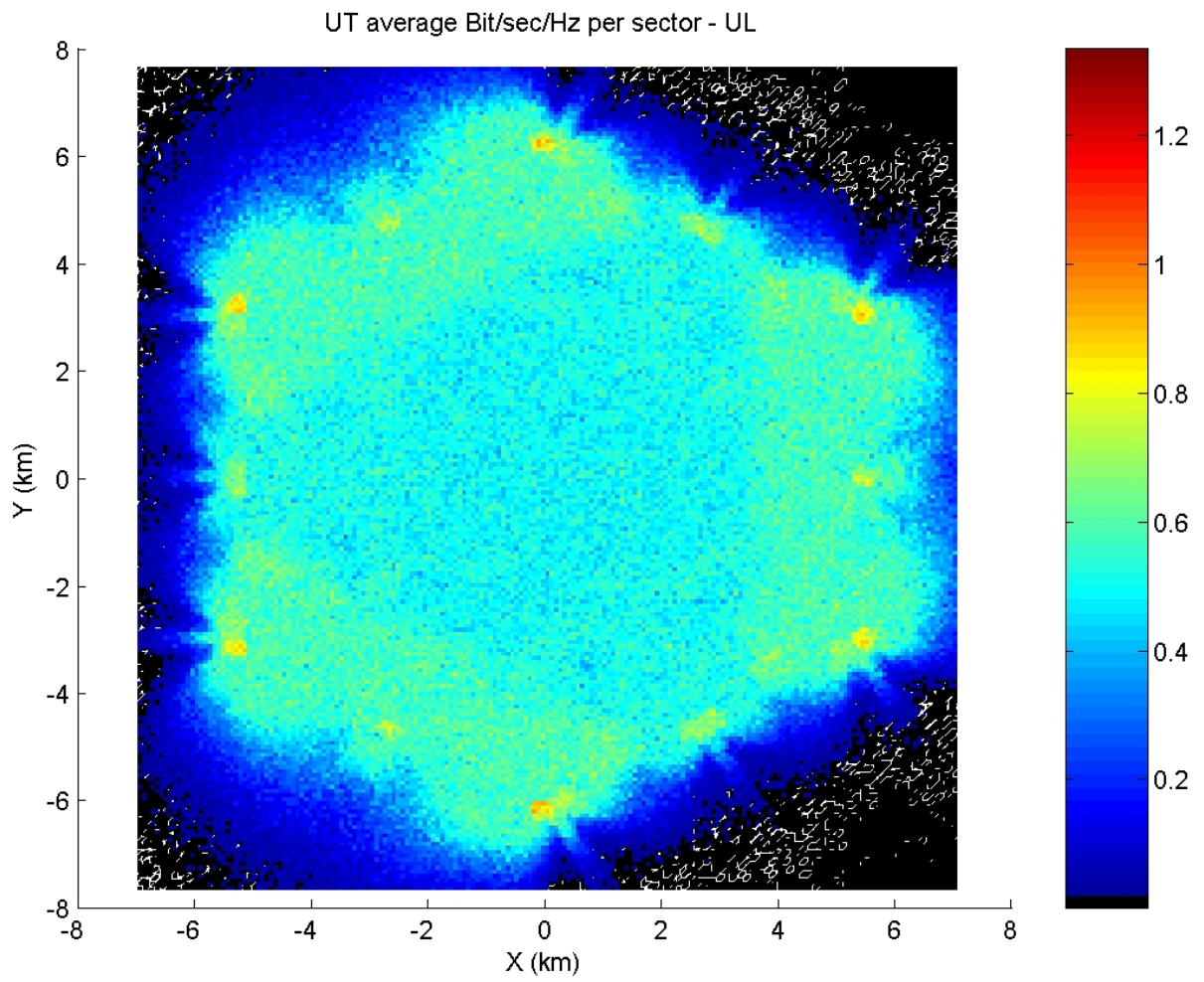


Figure 7: Average bit/sec/Hz per sector in the uplink - 3 sectors, reuse 1/3, ITU-B, 120Km/H

Scenario: 6 sectors, reuse 1/2, ITU-B, 120Km/H

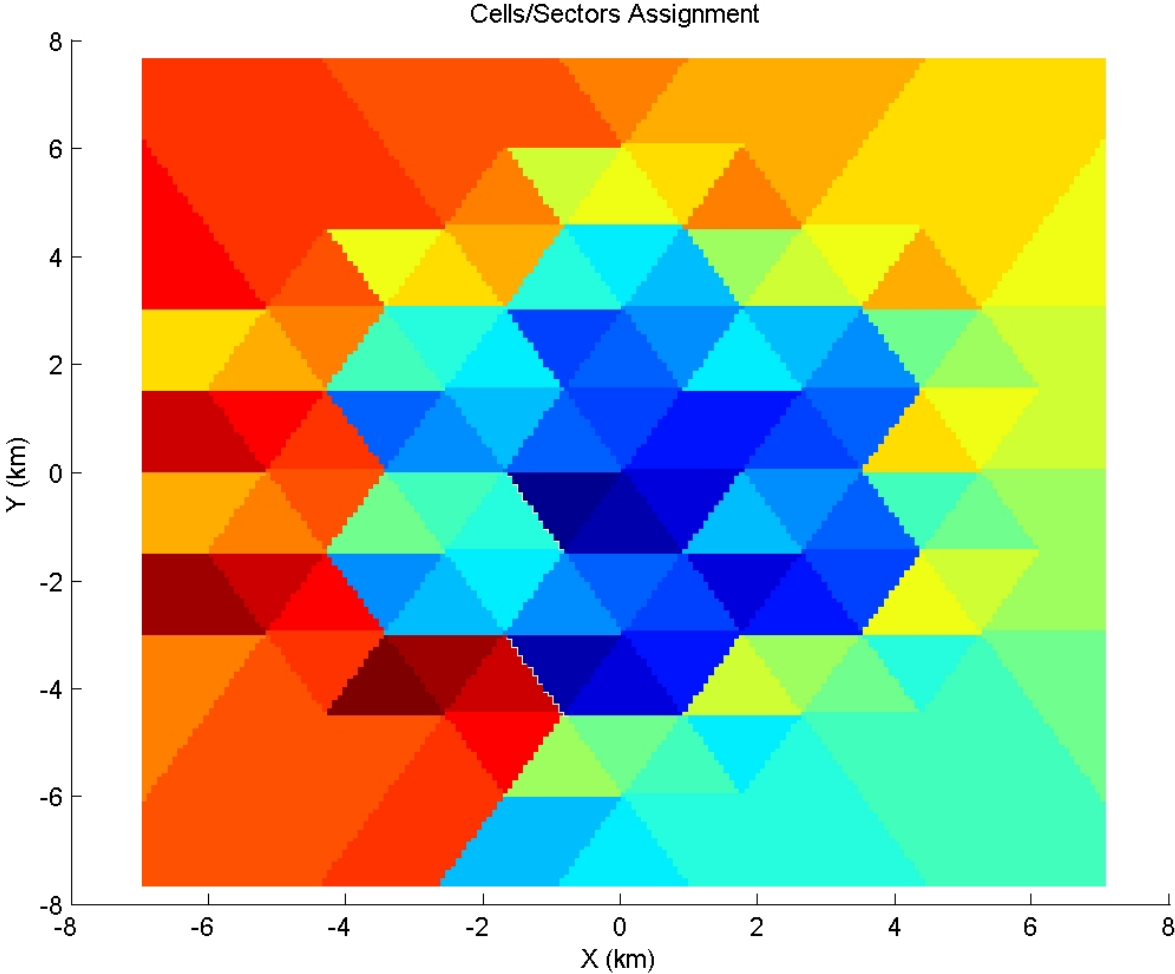


Figure 1: Cell/Sector Assignment - 6 sectors, reuse 1/2, ITU-B, 120Km/H

Coverage Statistics:

- Average DL throughput = 0.68 Bit/Sec/Hz per sector
- DL Coverage

- **FADE - 8.79%**
- QPSK, 1/8 - 11.10%
- QPSK, 1/4 - 20.98%
- QPSK, 1/2 - 16.50%
- QPSK, 3/4 - 10.84%
- 16QAM, 1/2 - 15.66%
- 16QAM, 3/4 - 6.51%
- 64QAM, 2/3 - 9.62%

- Average UL throughput = 0.58 Bit/Sec/Hz per sector
- UL Coverage

- **FADE - 5.88%**
- QPSK, 1/8 - 7.48%
- QPSK, 1/4 - 20.15%
- QPSK, 1/2 - 23.26%
- QPSK, 3/4 - 17.79%
- 16QAM, 1/2 - 21.79%
- 16QAM, 3/4 - 3.23%
- 64QAM, 2/3 - 0.43%

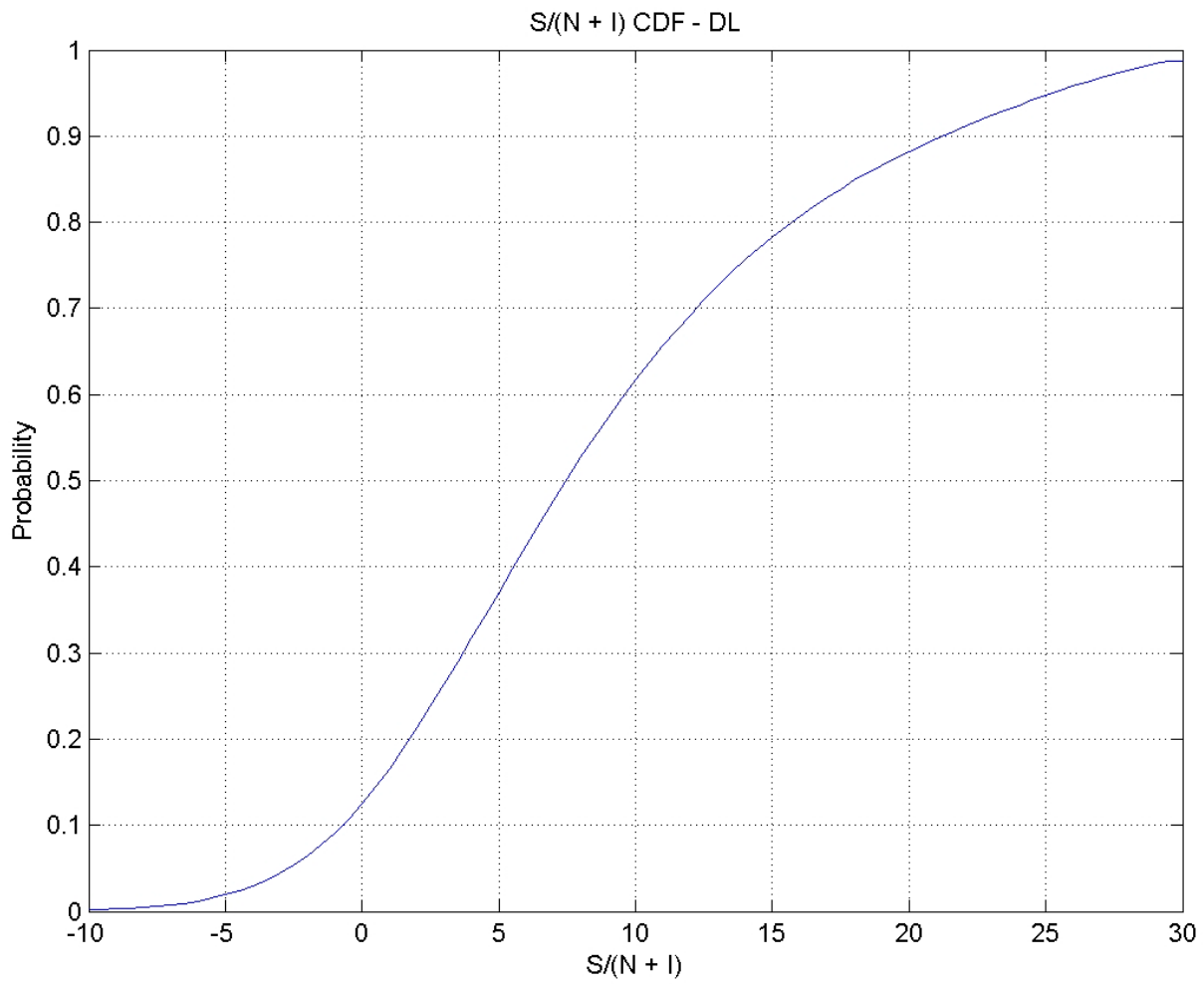


Figure 2: S/(N+I) Cumulative Distribution Function (CDF) in the downlink - 6 sectors, reuse 1/2, ITU-B, 120Km/H

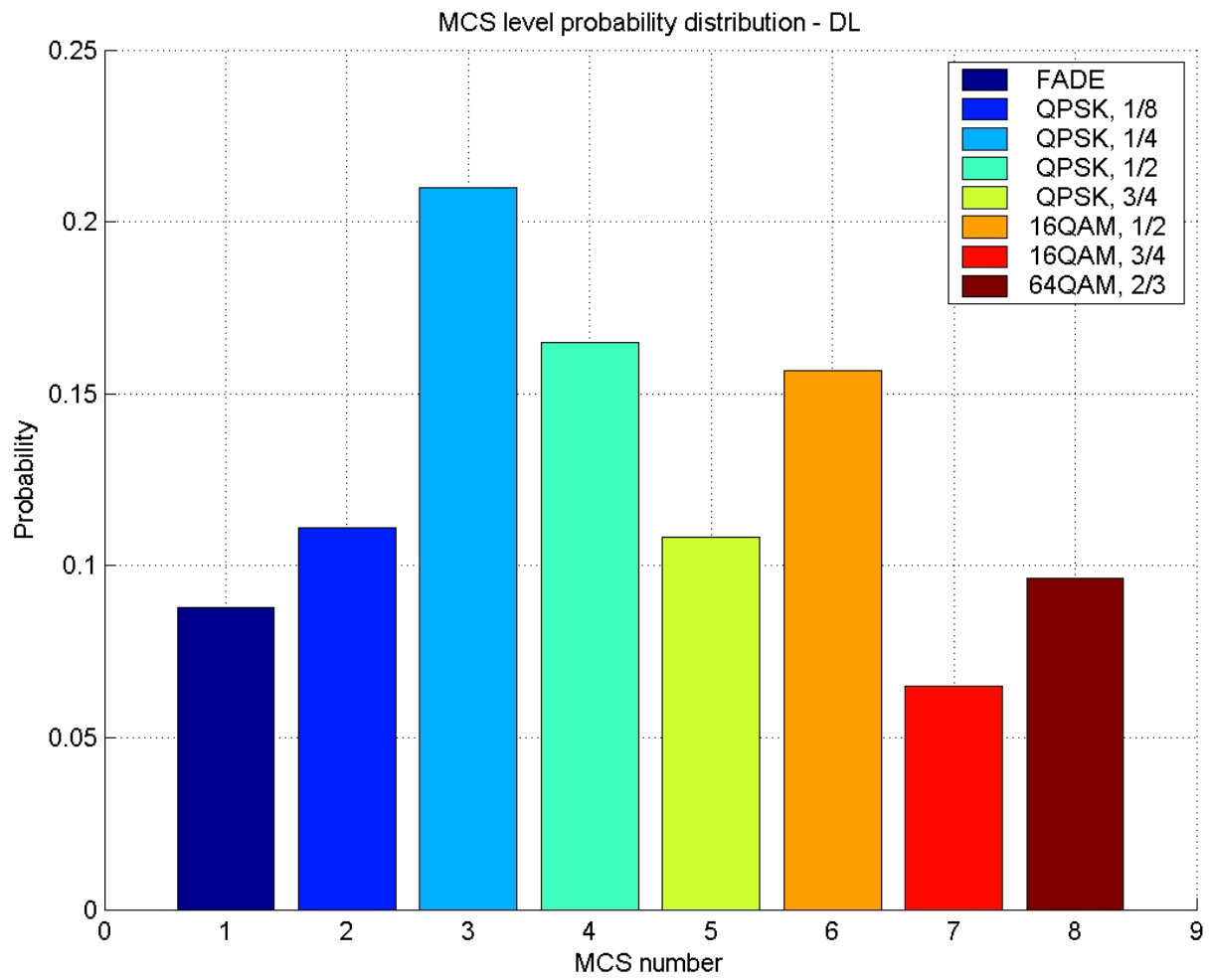


Figure 3: Modulation/Coding distribution in the downlink - 6 sectors, reuse 1/2, ITU-B, 120Km/H

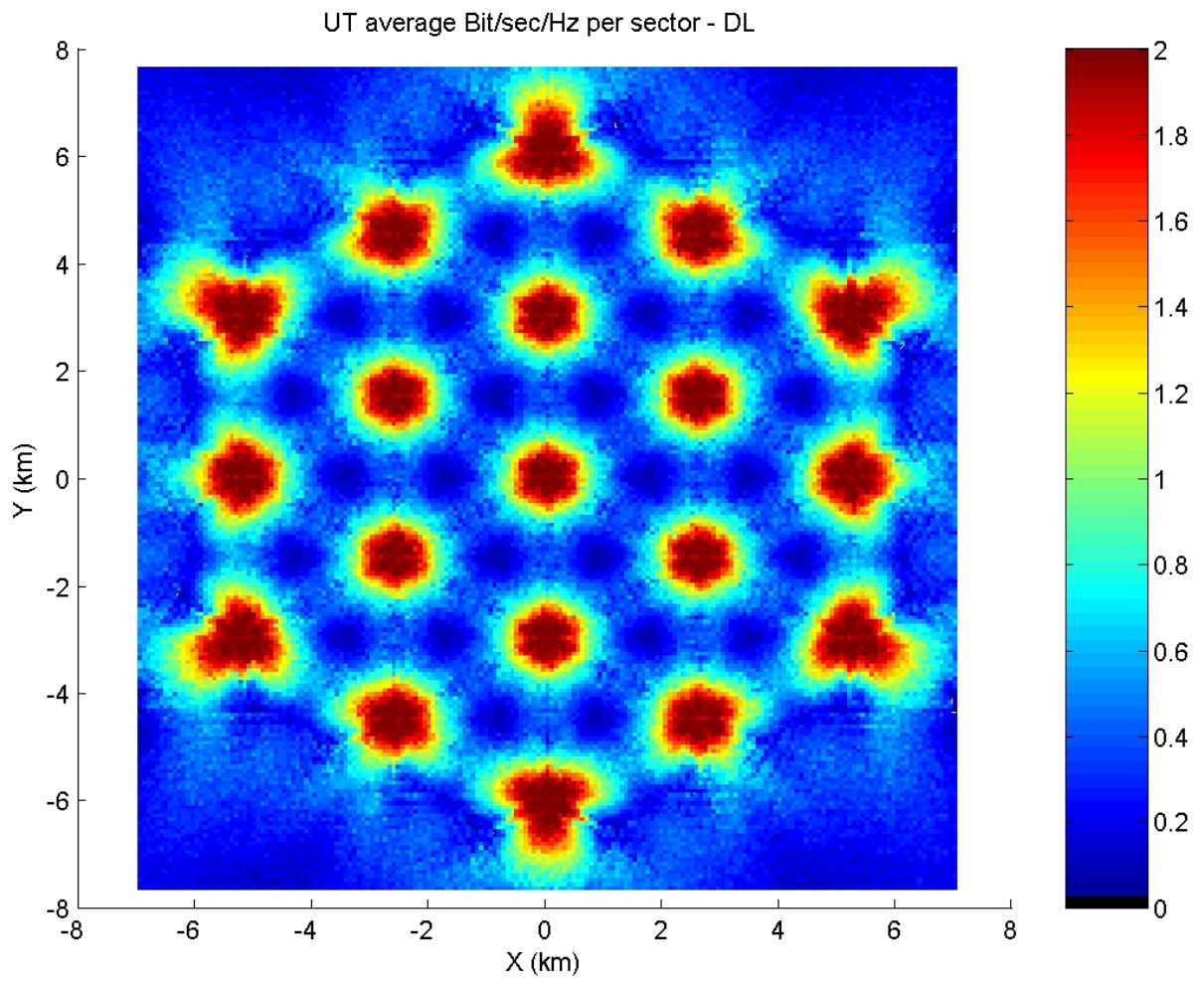


Figure 4: Average bit/sec/Hz per sector in the downlink - 6 sectors, reuse 1/2, ITU-B, 120Km/H

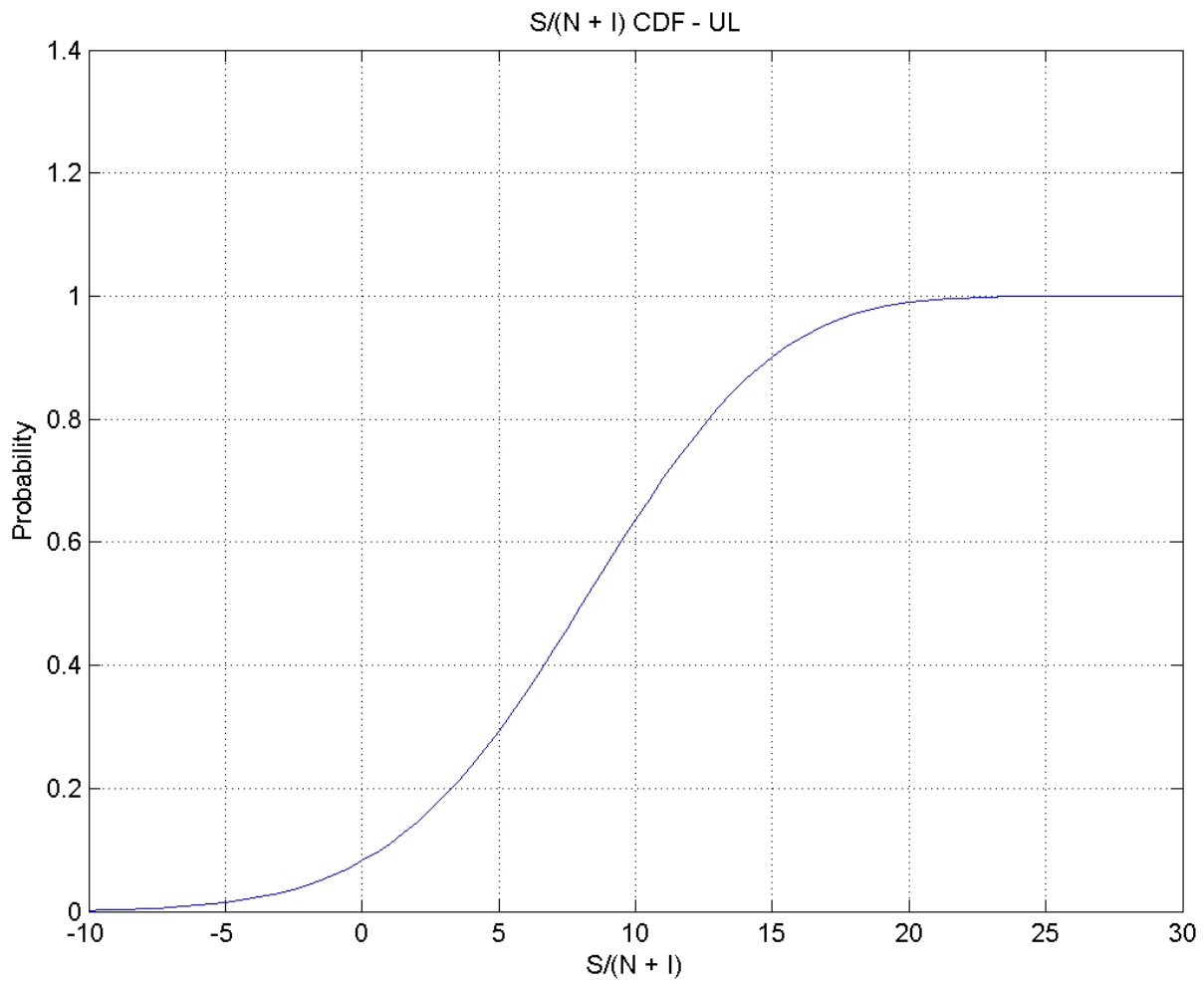


Figure 5: S/(N+I) Comulative Distribution Function (CDF) in the uplink - 6 sectors, reuse 1/2, ITU-B, 120Km/H

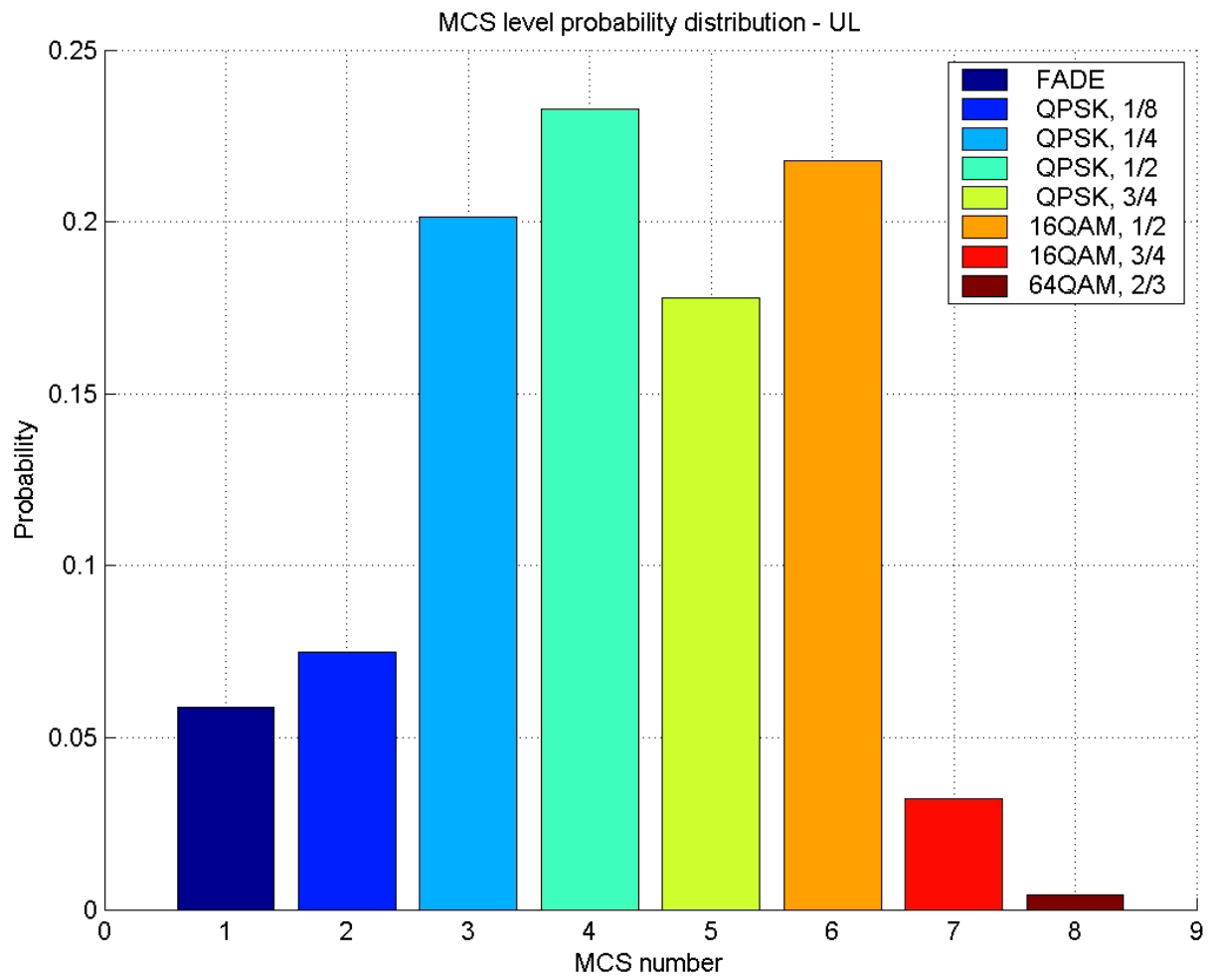


Figure 6: Modulation/Coding distribution in the uplink - 6 sectors, reuse 1/2, ITU-B, 120Km/H

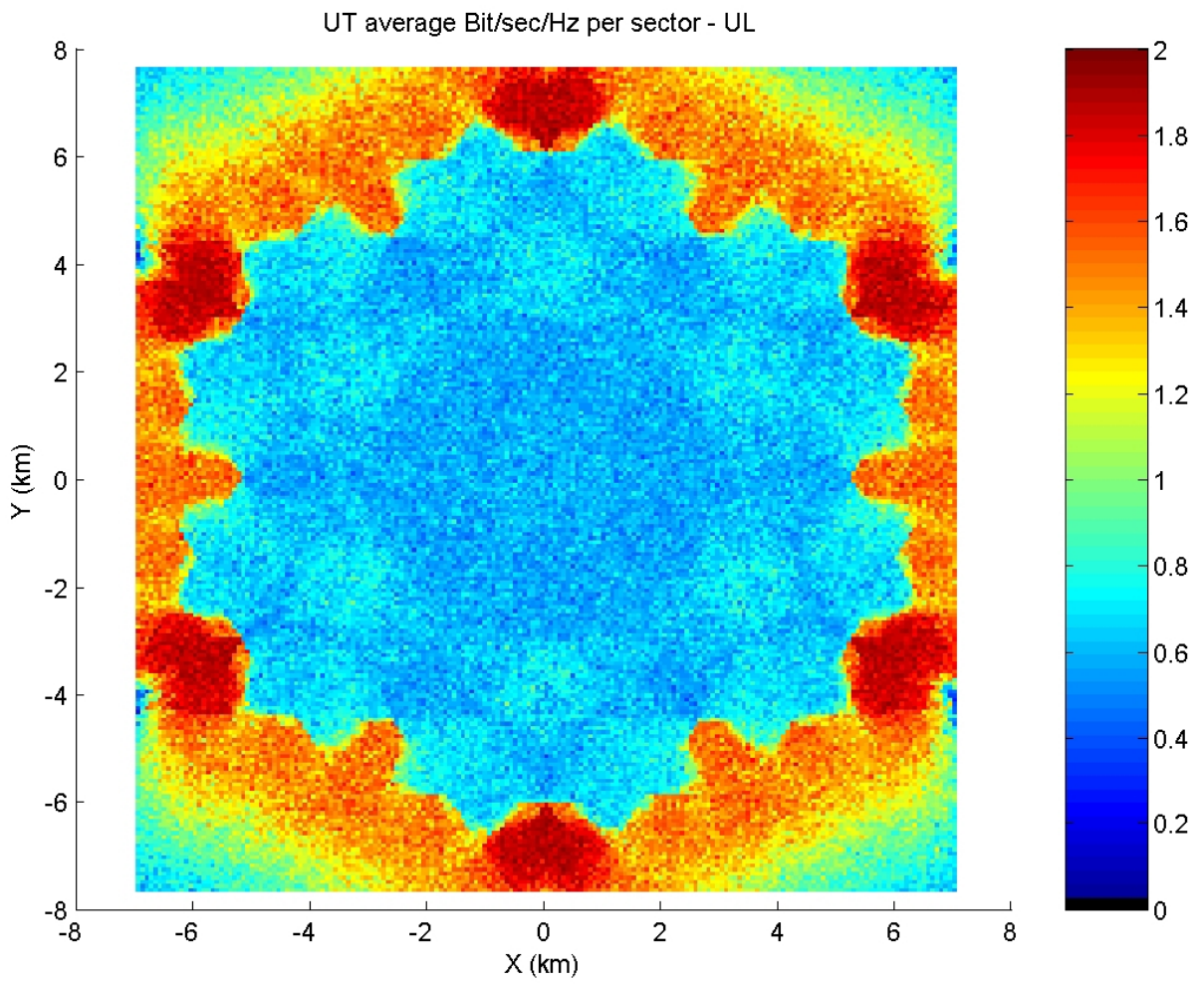


Figure 7: Average bit/sec/Hz per sector in the uplink - 6 sectors, reuse 1/2, ITU-B, 120Km/H

Scenario: 2 Antenna STC, Omni, reuse 1, ITU-B,120Km/H

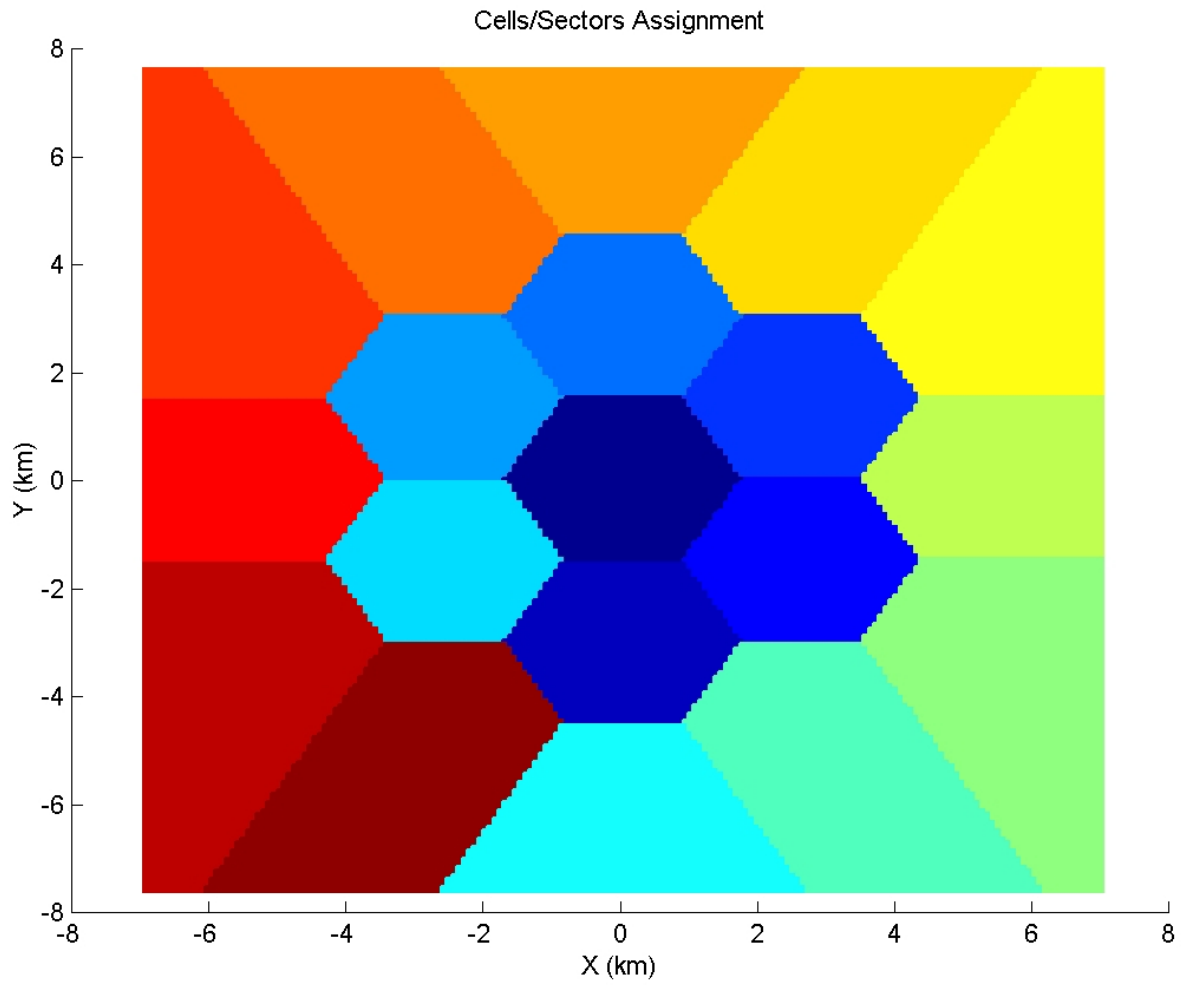


Figure 1: Cell/Sector Assignment - 2 Antenna STC, Omni, reuse 1, ITU-B,120Km/H

Coverage Statistics:

- Average DL throughput = 1.41 Bit/Sec/Hz per sector
- DL Coverage

- **FADE - 10.21%**
- QPSK, 1/8 - 10.55%
- QPSK, 1/4 - 24.57%
- QPSK, 1/2 - 13.90%
- QPSK, 3/4 - 8.27%
- 16QAM, 1/2 - 10.82%
- 16QAM, 3/4 - 8.10%
- 64QAM, 2/3 - 13.59%

- Average UL throughput = 0.99 Bit/Sec/Hz per sector
- UL Coverage

- **FADE - 10.69%**
- QPSK, 1/8 - 8.72%
- QPSK, 1/4 - 26.91%
- QPSK, 1/2 - 21.55%
- QPSK, 3/4 - 13.87%
- 16QAM, 1/2 - 13.74%
- 16QAM, 3/4 - 4.15%
- 64QAM, 2/3 - 0.36%

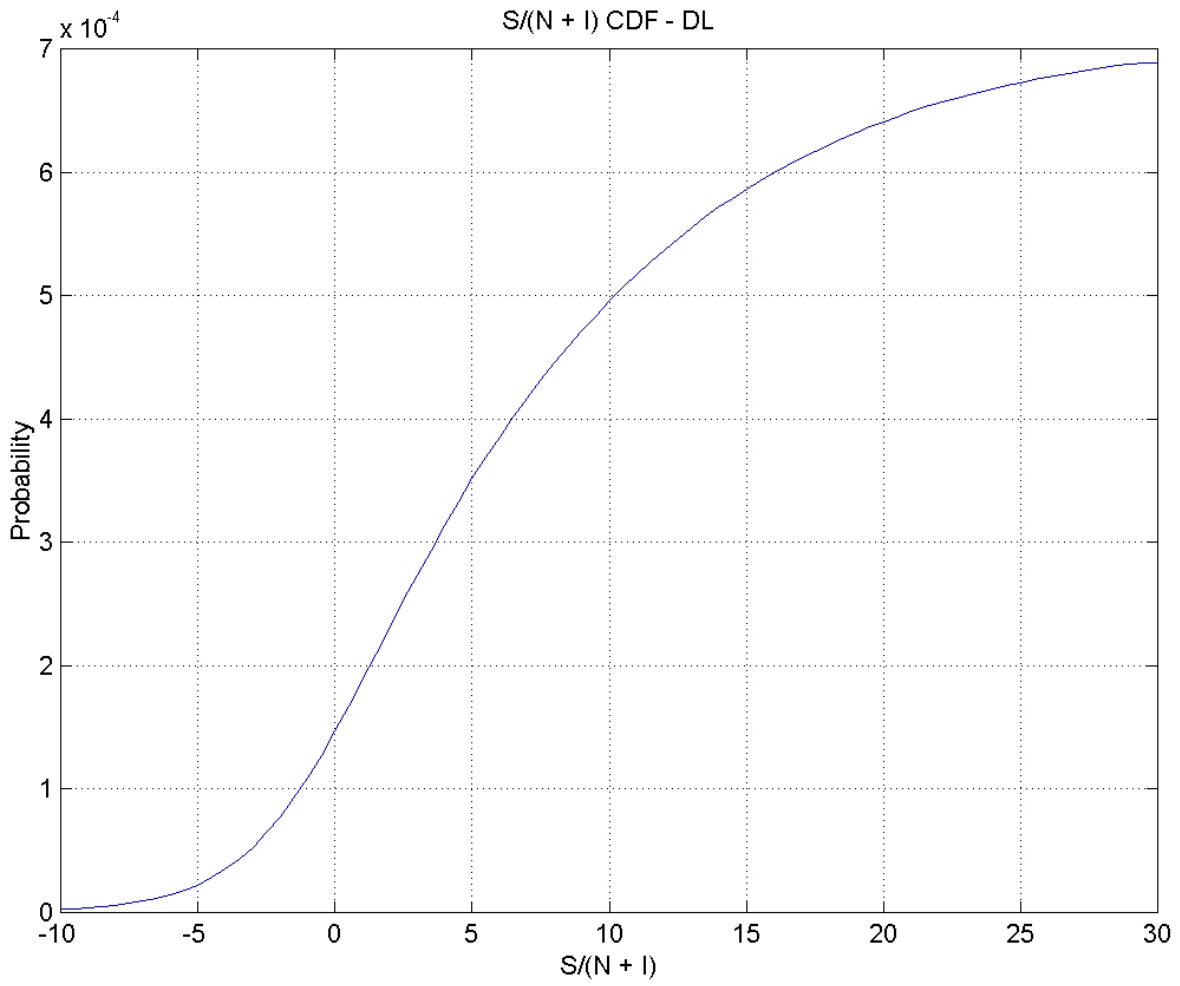


Figure 2: S/(N+I) Cumulative Distribution Function (CDF) in the downlink - 2 Antenna STC, Omni, reuse 1, ITU-B,120Km/H

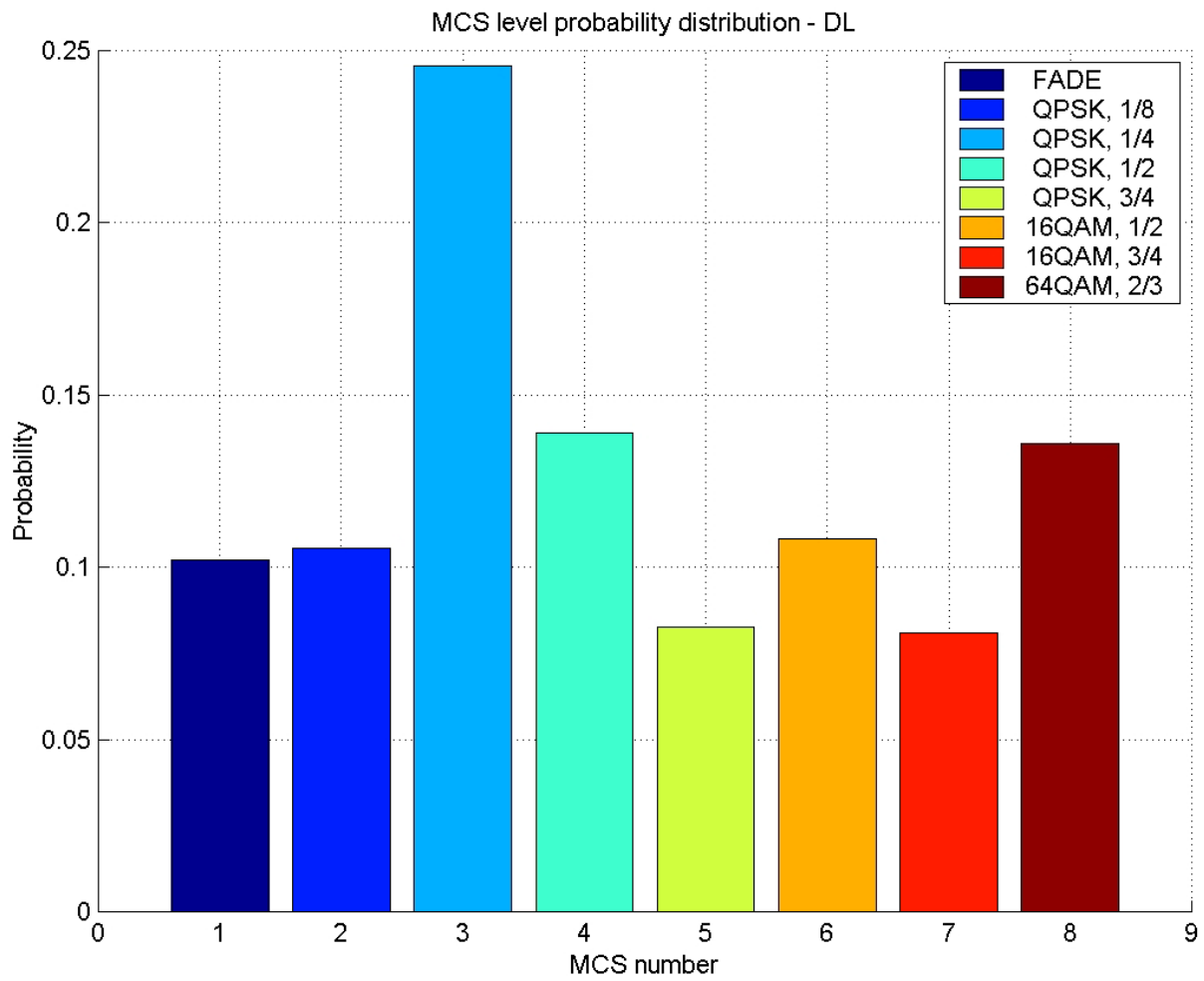


Figure 3: Modulation/Coding distribution in the downlink - 2 Antenna STC, Omni, reuse 1, ITU-B,120Km/H

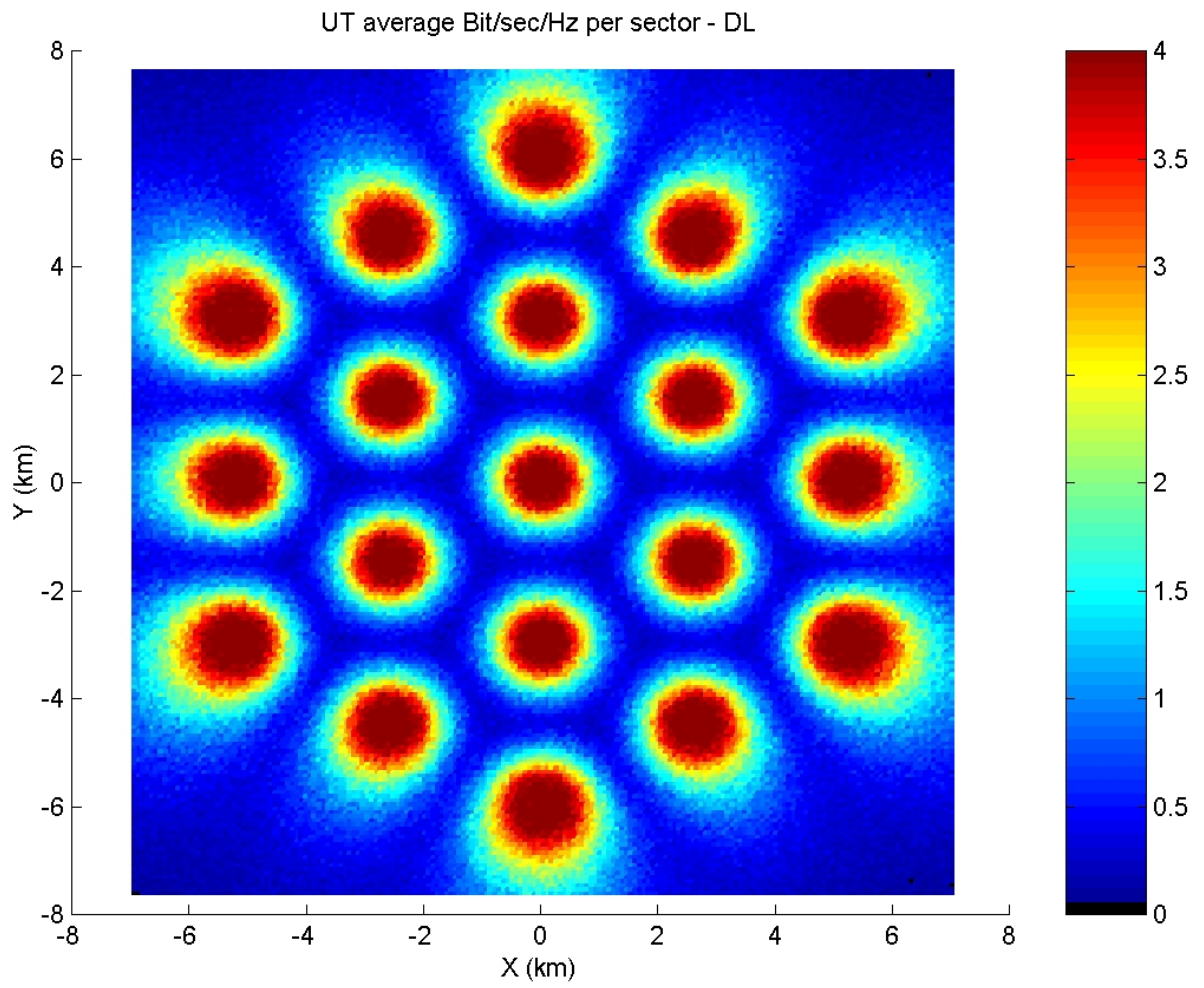


Figure 4: Average bit/sec/Hz per sector in the downlink - 2 Antenna STC, Omni, reuse 1, ITU-B,120Km/H

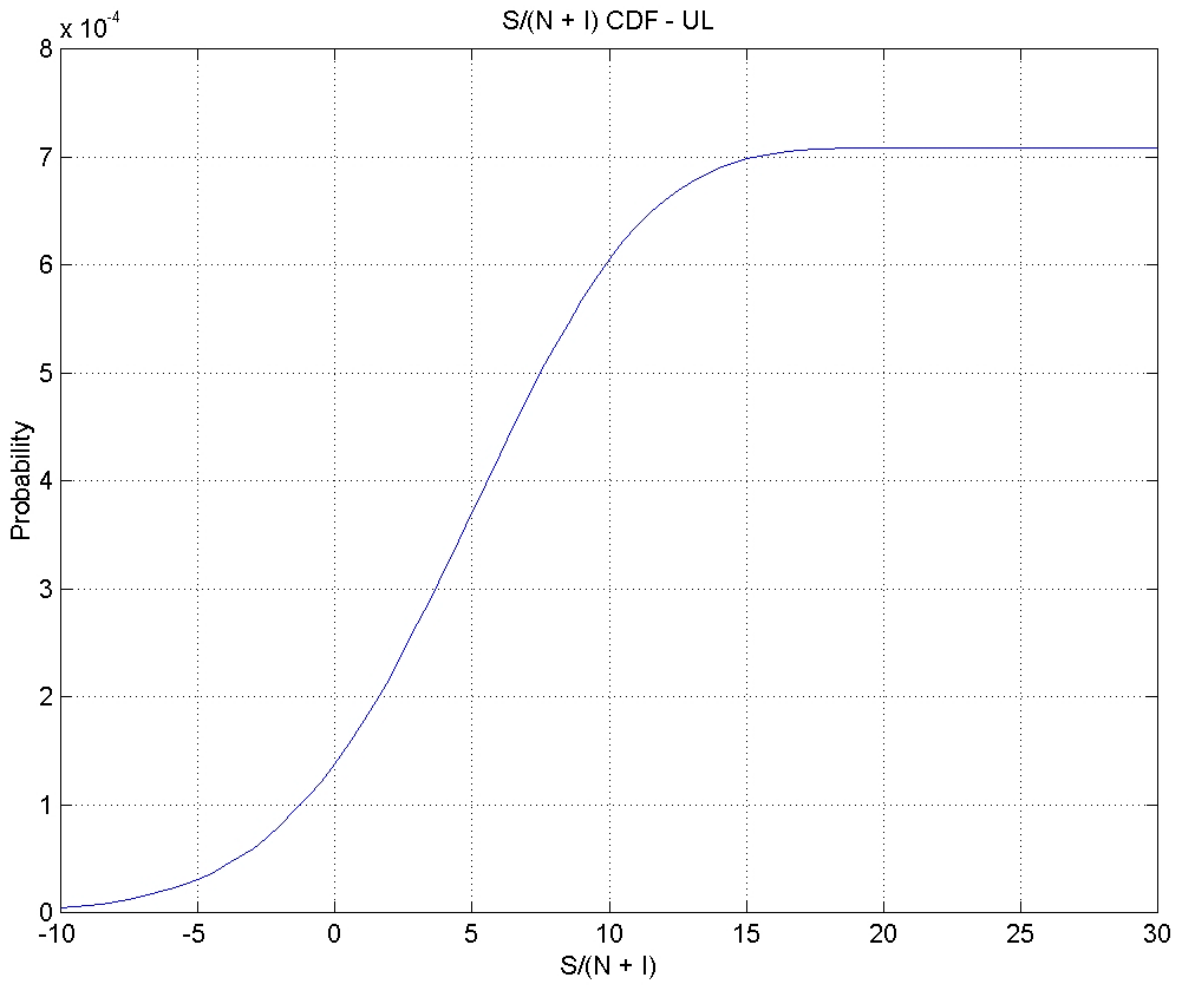


Figure 5: S/(N+I) Cumulative Distribution Function (CDF) in the uplink - 2 Antenna STC, Omni, reuse 1, ITU-B,120Km/H

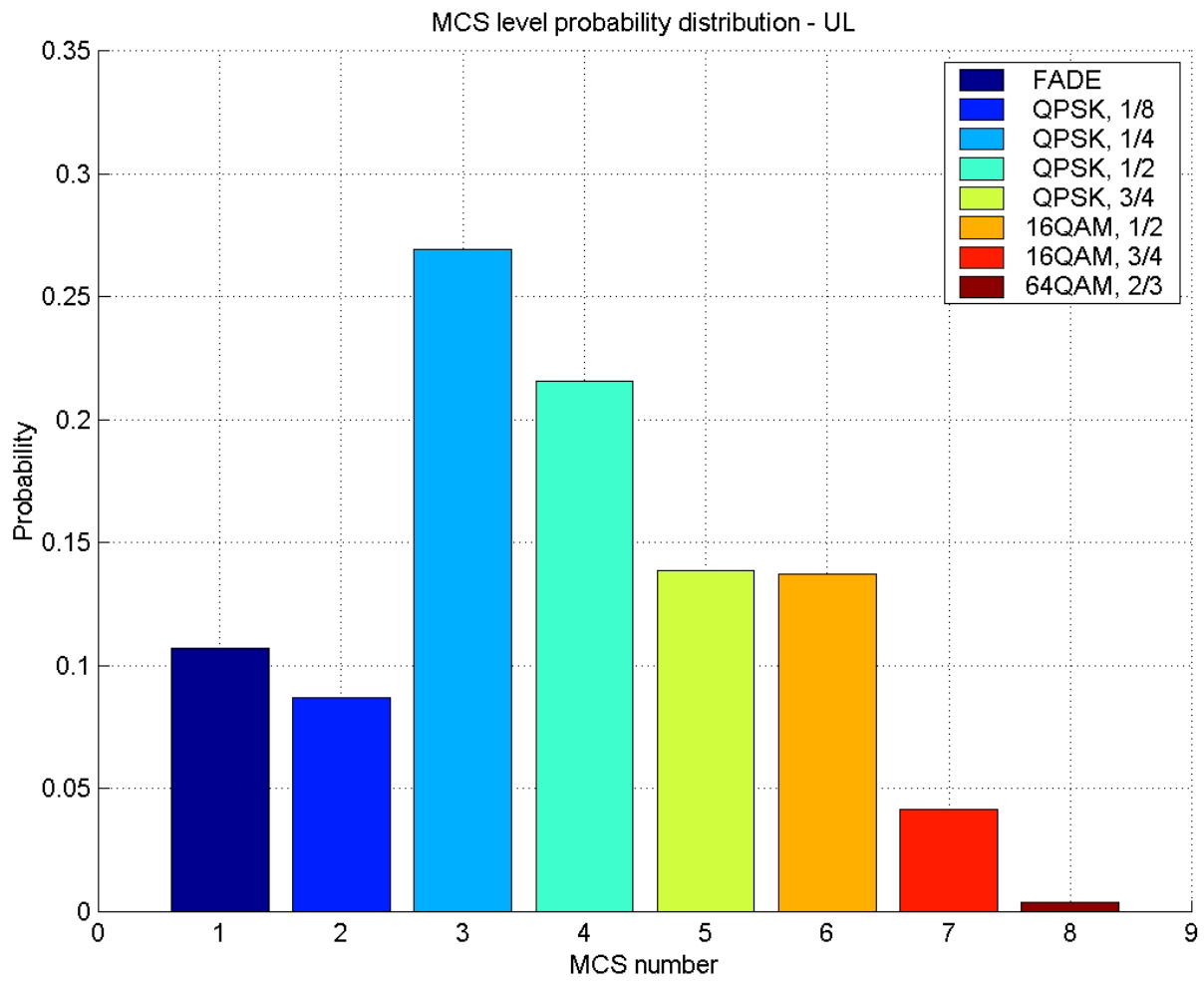


Figure 6: Modulation/Coding distribution in the uplink - 2 Antenna STC, Omni, reuse 1, ITU-B,120Km/H

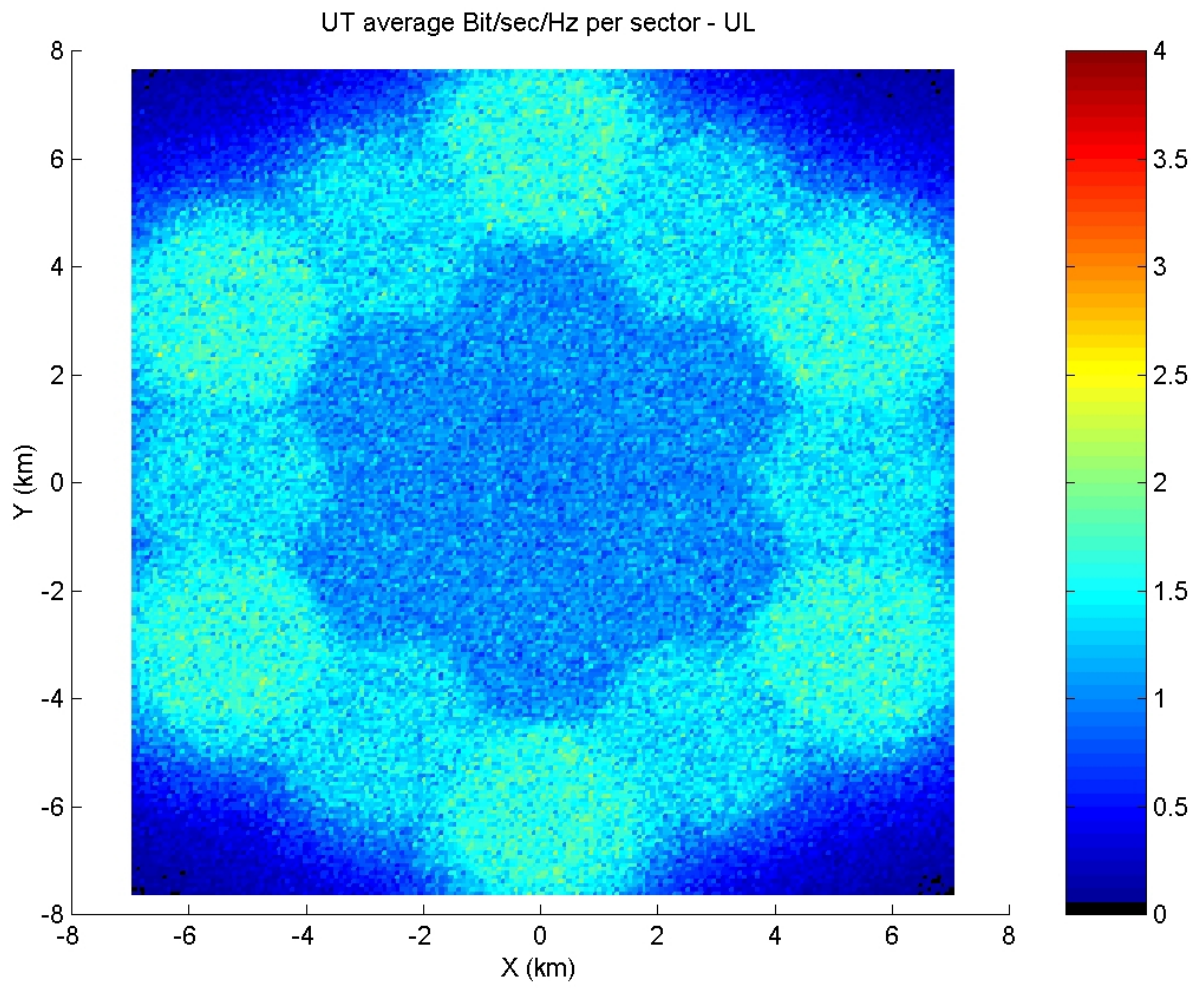


Figure 7: Average bit/sec/Hz per sector in the uplink - 2 Antenna STC, Omni, reuse 1, ITU-B,120Km/H

Scenario: 2 Antenna STC, 3 sectors, reuse 1, ITU-B,120Km/H

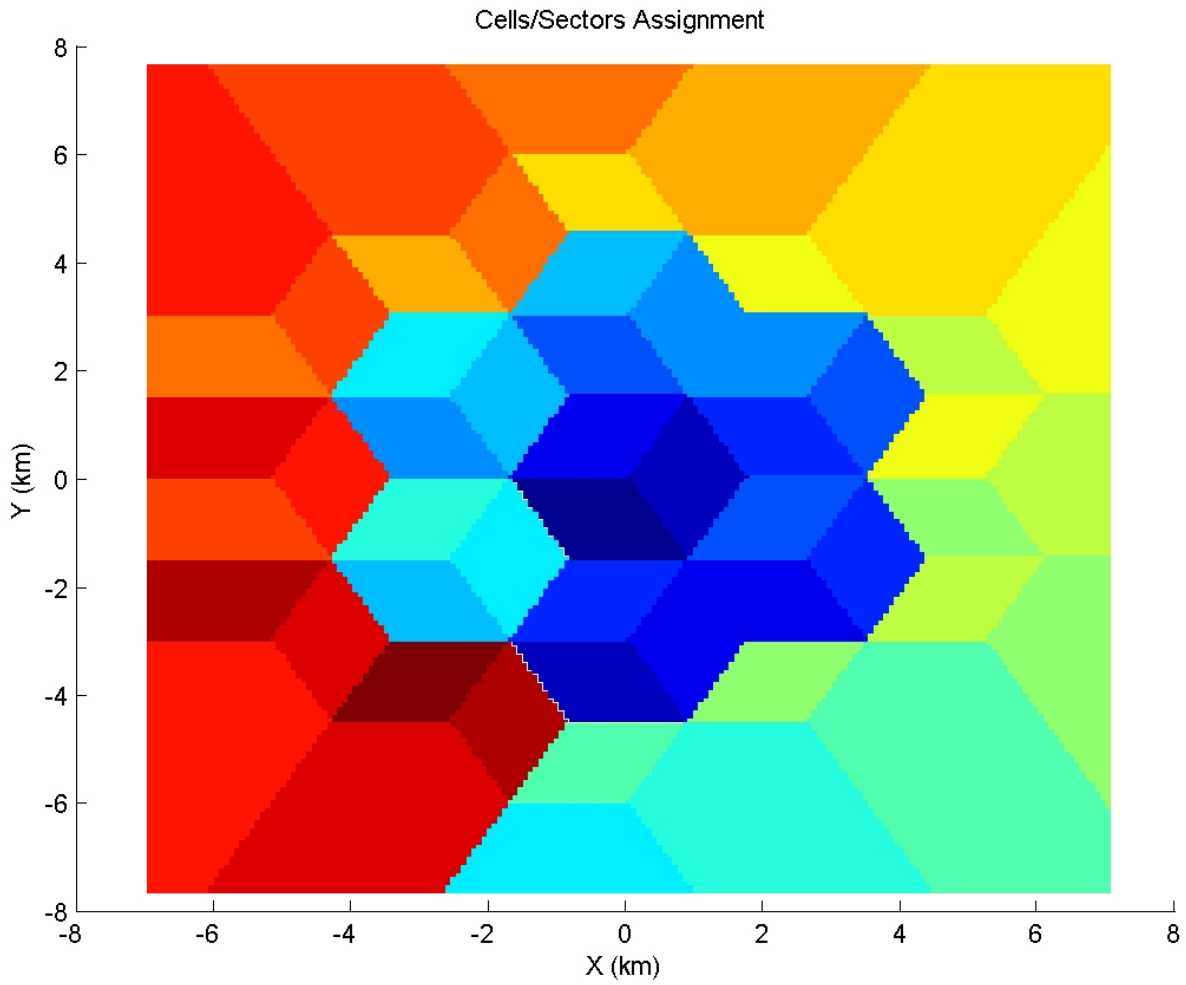


Figure 1: Cell/Sector Assignment - 2 Antenna STC, 3 sectors, reuse 1, ITU-B,120Km/H

Coverage Statistics:

- Average DL throughput = 0.57 Bit/Sec/Hz per sector
- DL Coverage

- **FADE - 25.11%**
- QPSK, 1/8 - 16.98%
- QPSK, 1/4 - 31.25%
- QPSK, 1/2 - 13.68%
- QPSK, 3/4 - 6.88%
- 16QAM, 1/2 - 5.67%
- 16QAM, 3/4 - 0.44%
- 64QAM, 2/3 - 0.00%

- Average UL throughput = 0.51 Bit/Sec/Hz per sector
- UL Coverage

- **FADE - 29.60%**
- QPSK, 1/8 - 16.02%
- QPSK, 1/4 - 30.25%
- QPSK, 1/2 - 13.98%
- QPSK, 3/4 - 5.92%
- 16QAM, 1/2 - 3.61%
- 16QAM, 3/4 - 0.61%
- 64QAM, 2/3 - 0.02%

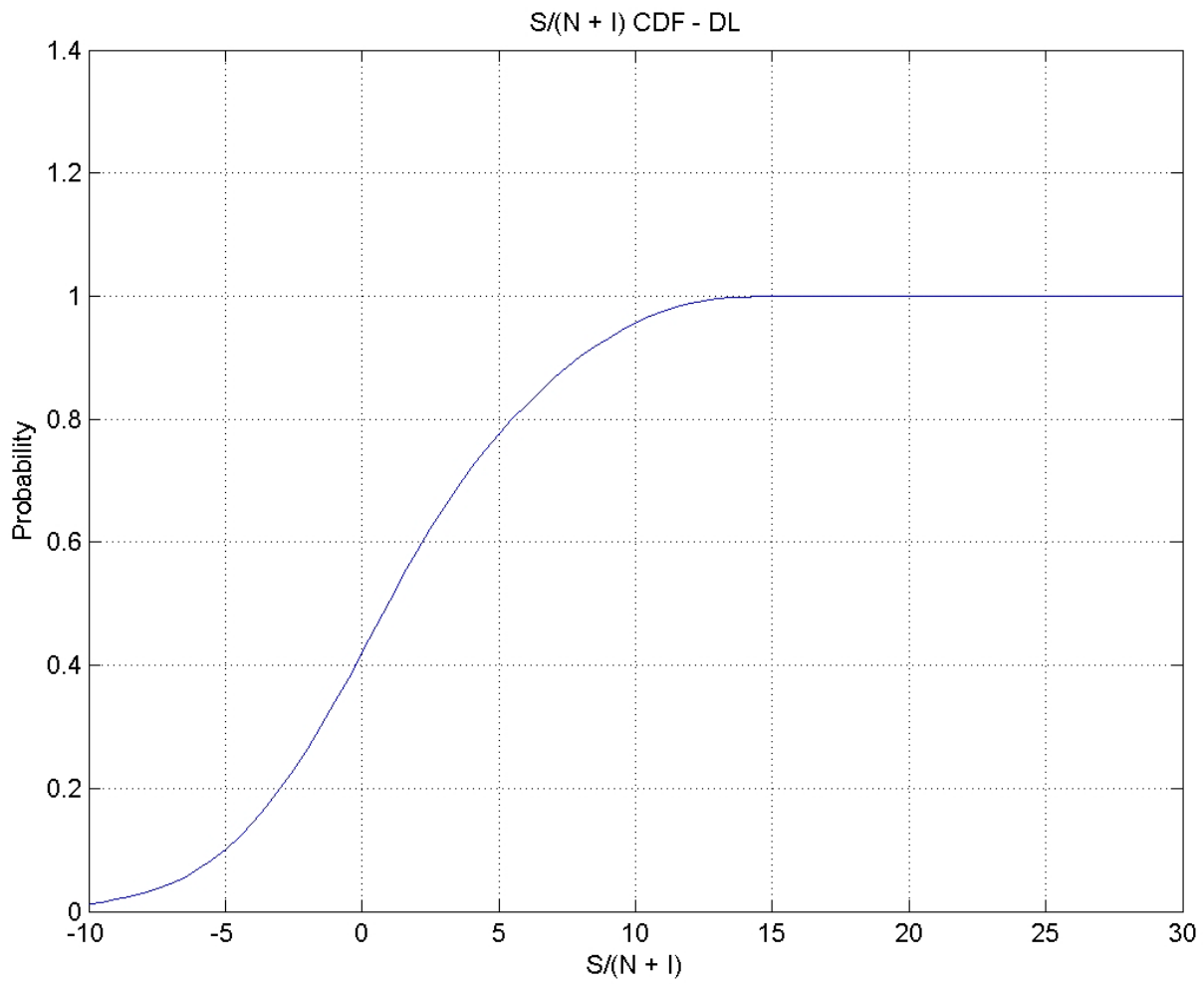


Figure 2: $S/(N+I)$ Cumulative Distribution Function (CDF) in the downlink - 2 Antenna STC, 3 sectors, reuse 1, ITU-B, 120Km/H

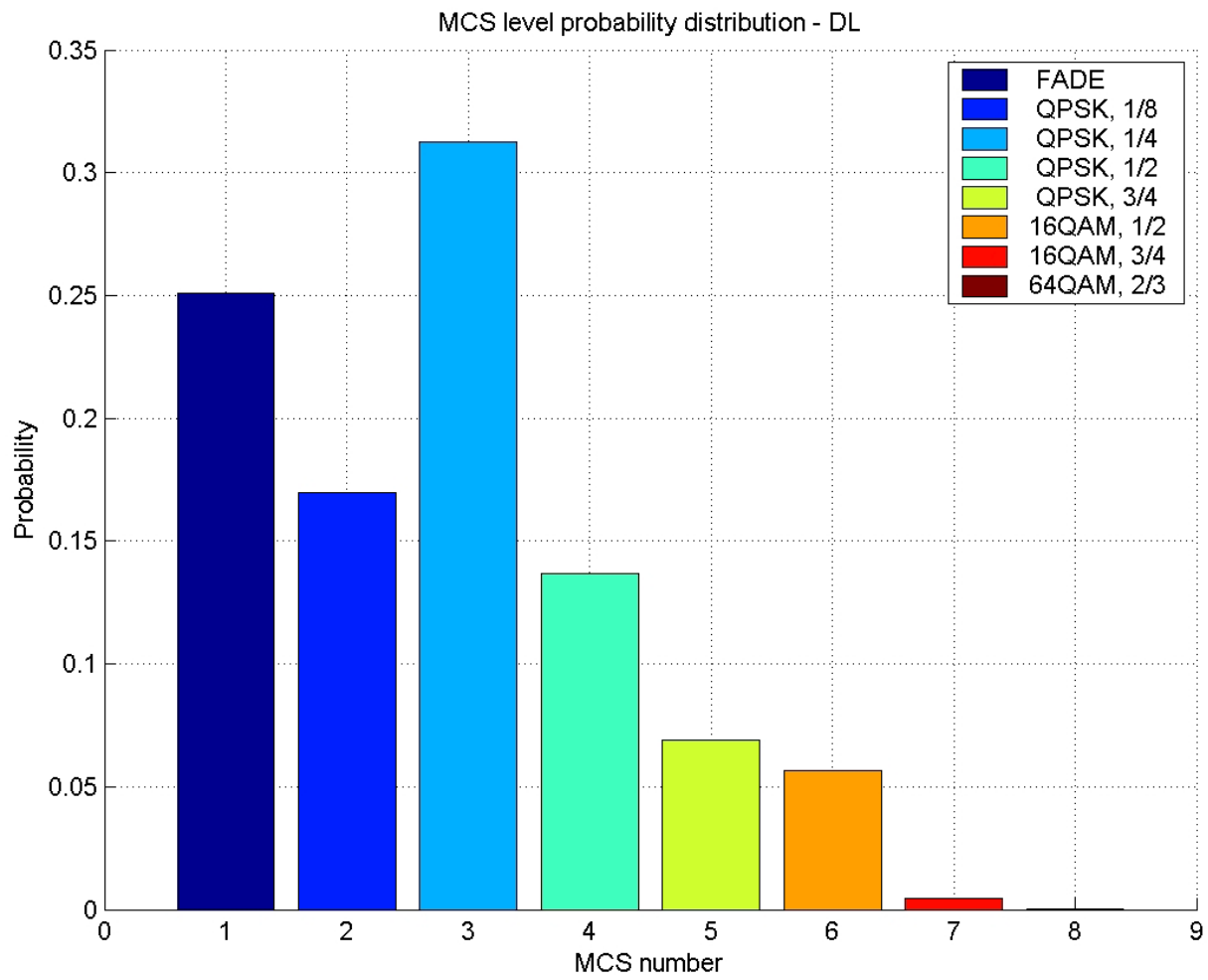


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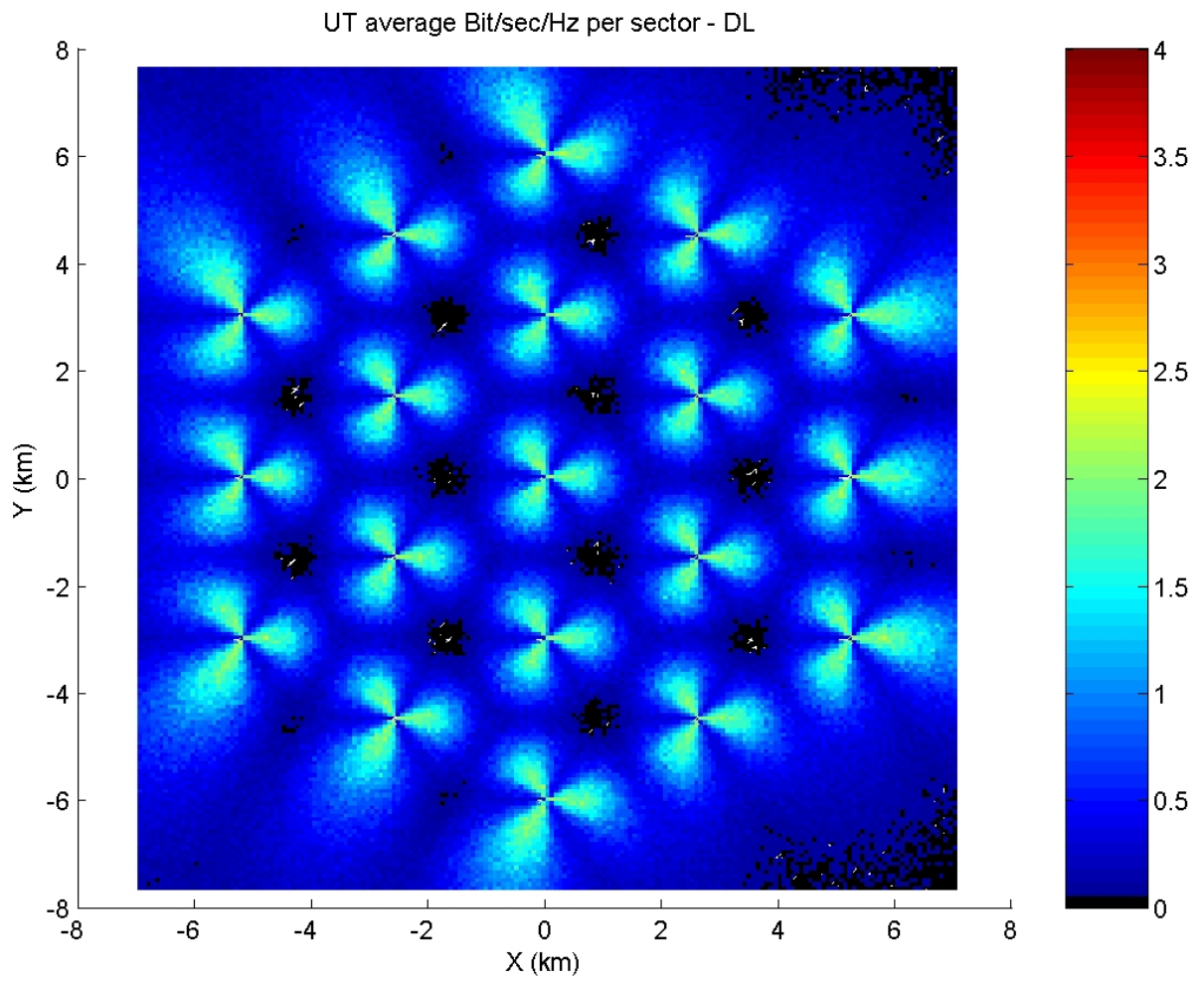


Figure 4: Average bit/sec/Hz per sector in the downlink - 2 Antenna STC, 3 sectors, reuse 1, ITU-B,120Km/H

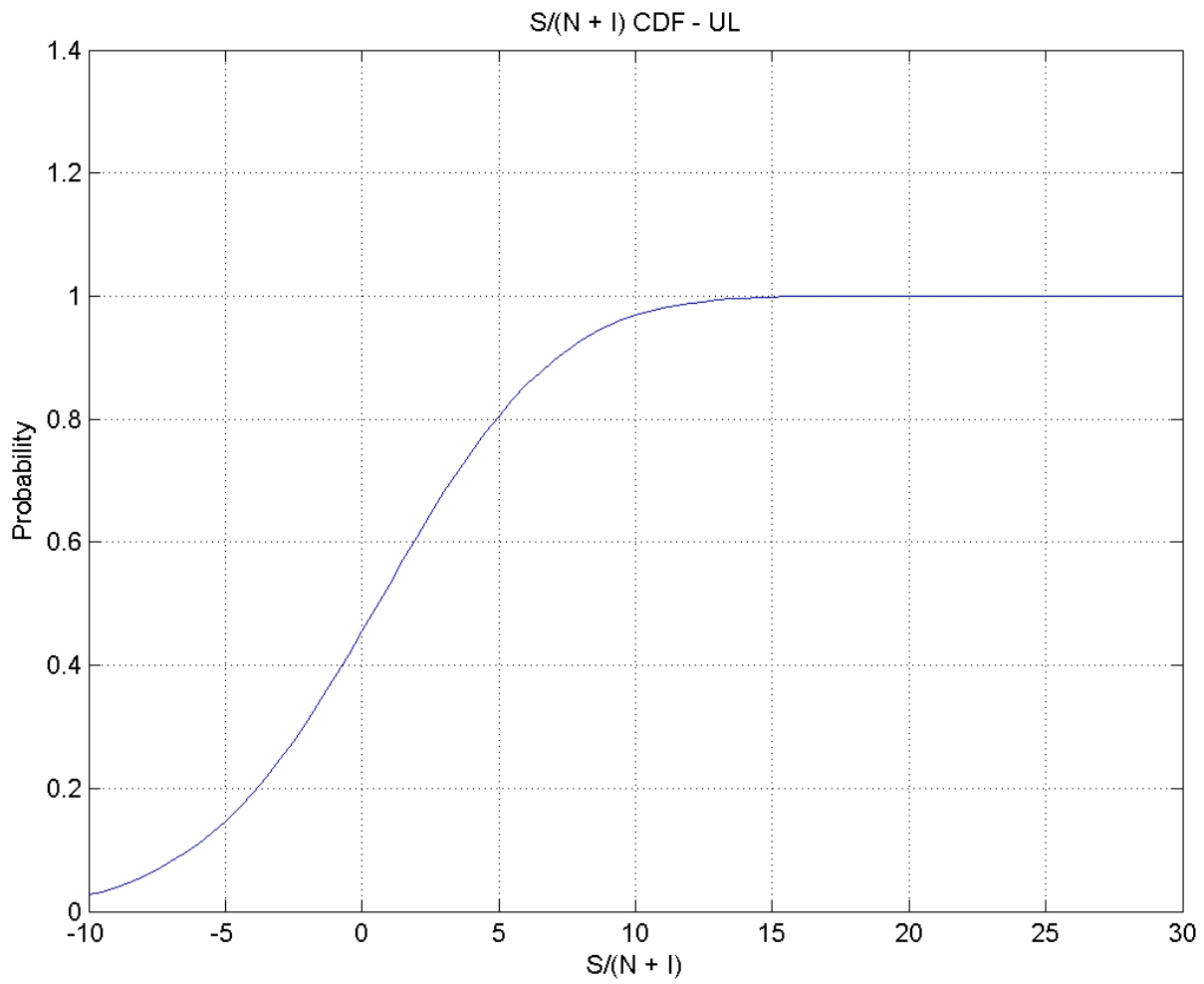


Figure 5: $S/(N+I)$ Cumulative Distribution Function (CDF) in the uplink - 2 Antenna STC, 3 sectors, reuse 1, ITU-B, 120Km/H

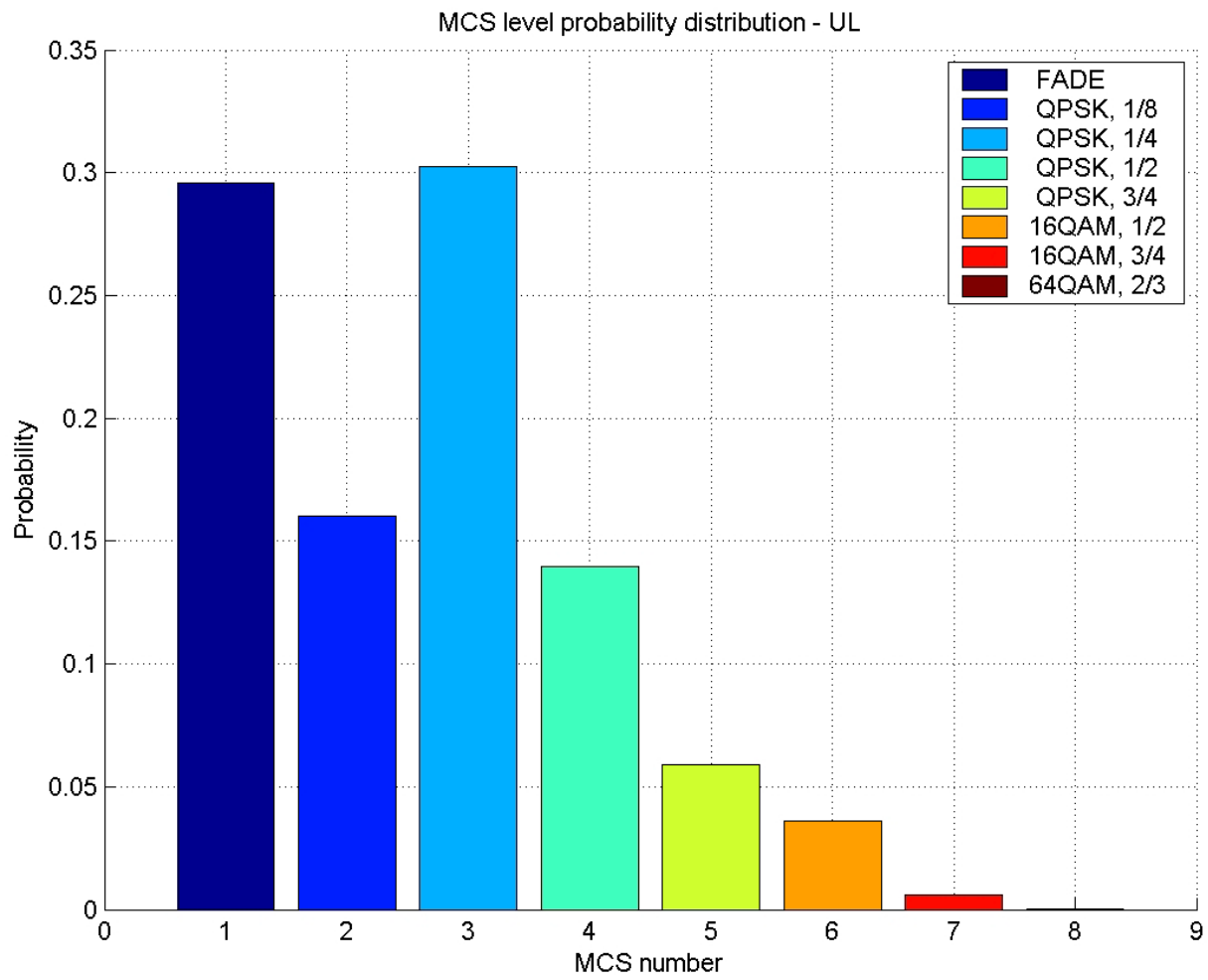


Figure 6: Modulation/Coding distribution in the uplink - 2 Antenna STC, 3 sectors, reuse 1, ITU-B,120Km/H

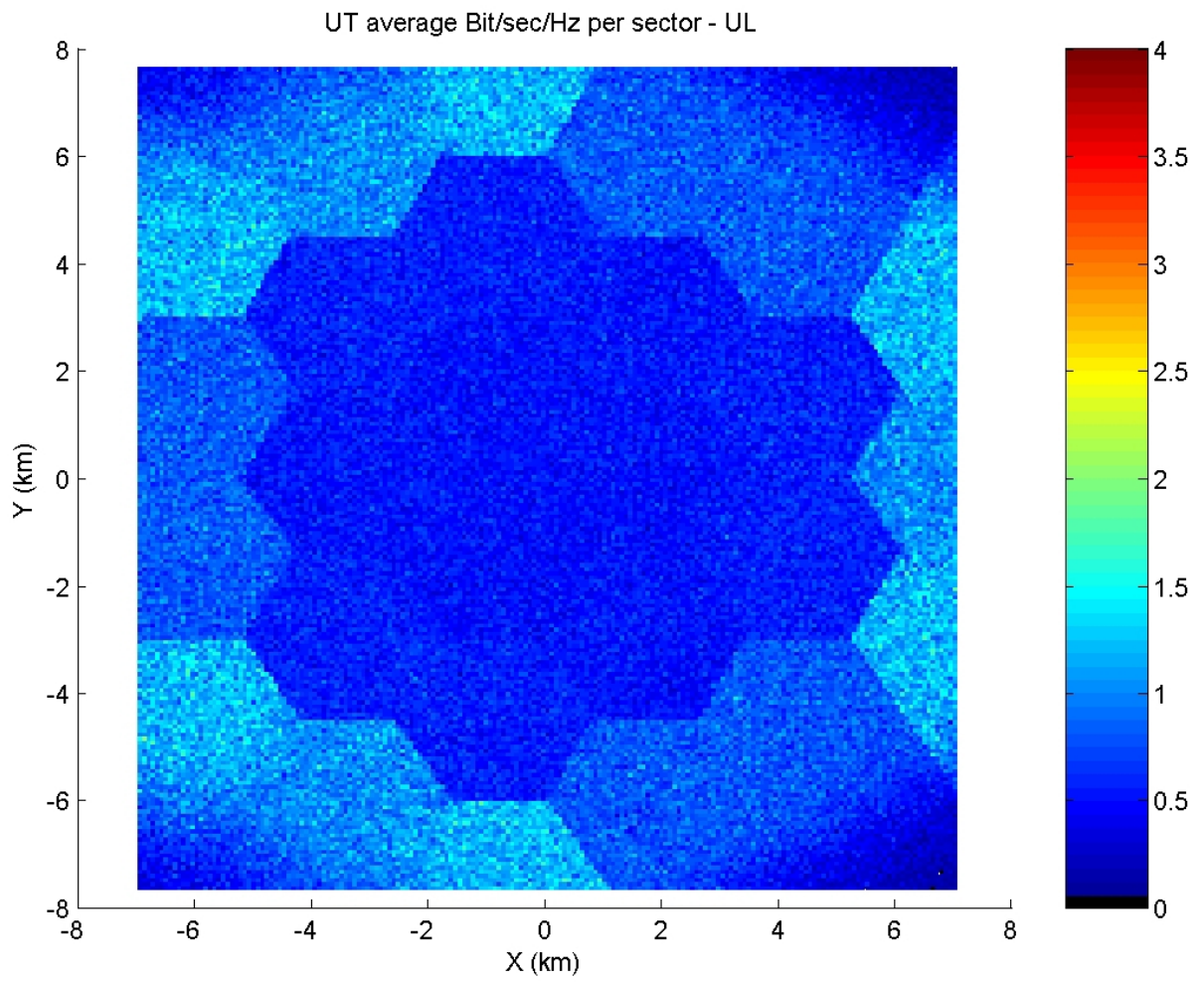


Figure 7: Average bit/sec/Hz per sector in the uplink - 2 Antenna STC, 3 sectors, reuse 1, ITU-B,120Km/H

Scenario: 2 Antenna STC, 3 sectors, reuse 1/3, ITU-B,120Km/H

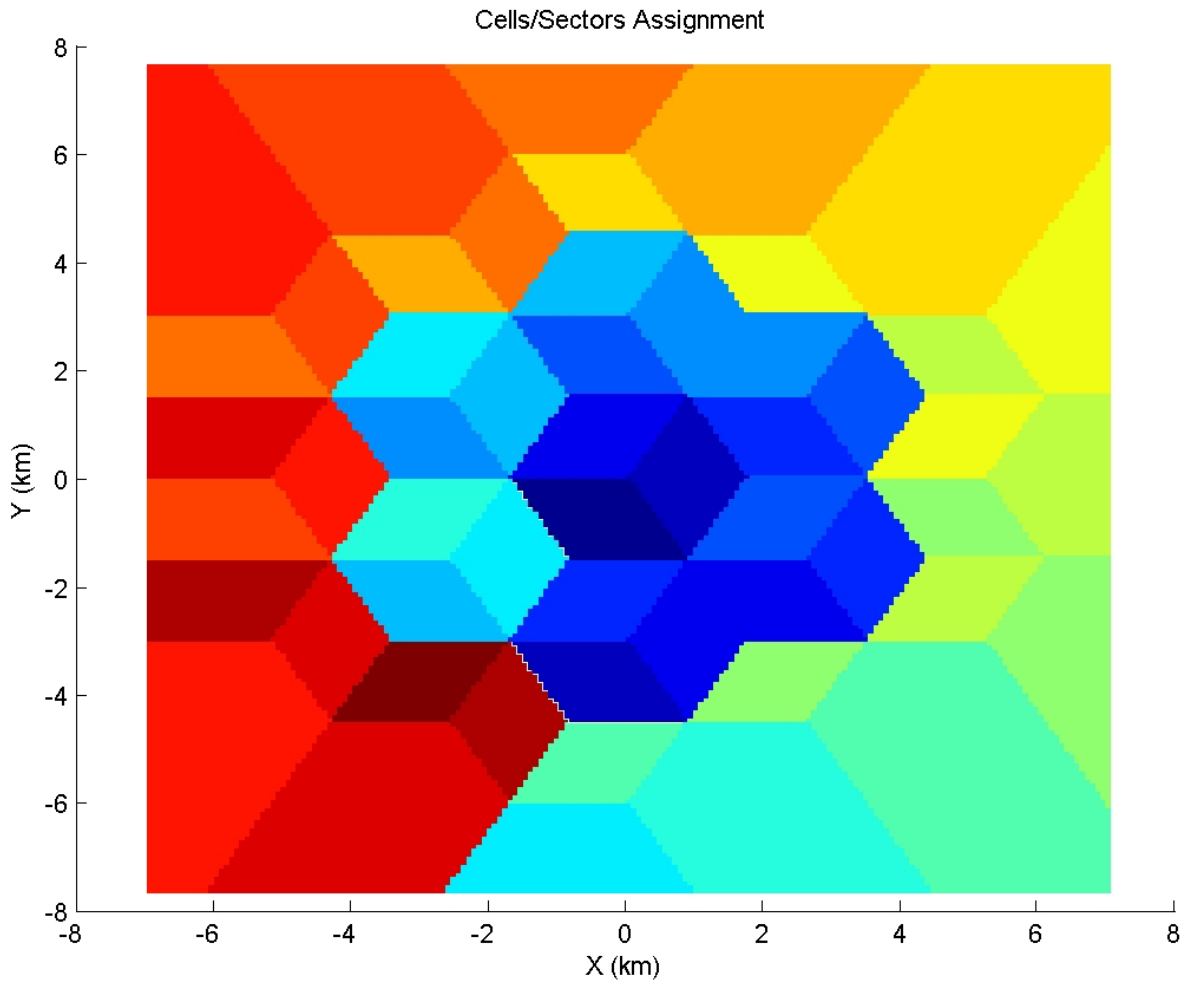


Figure 1: Cell/Sector Assignment - 2 Antenna STC, 3 sectors, reuse 1/3, ITU-B,120Km/H

Coverage Statistics:

- Average DL throughput = 0.70 Bit/Sec/Hz per sector
- DL Coverage

- **FADE - 3.03%**
- QPSK, 1/8 - 4.06%
- QPSK, 1/4 - 14.64%
- QPSK, 1/2 - 13.15%
- QPSK, 3/4 - 10.28%
- 16QAM, 1/2 - 16.12%
- 16QAM, 3/4 - 14.18%
- 64QAM, 2/3 - 24.53%

- Average UL throughput = 0.65 Bit/Sec/Hz per sector
- UL Coverage

- **FADE - 1.21%**
- QPSK, 1/8 - 1.68%
- QPSK, 1/4 - 8.65%
- QPSK, 1/2 - 14.05%
- QPSK, 3/4 - 15.30%
- 16QAM, 1/2 - 29.97%
- 16QAM, 3/4 - 22.86%
- 64QAM, 2/3 - 6.27%

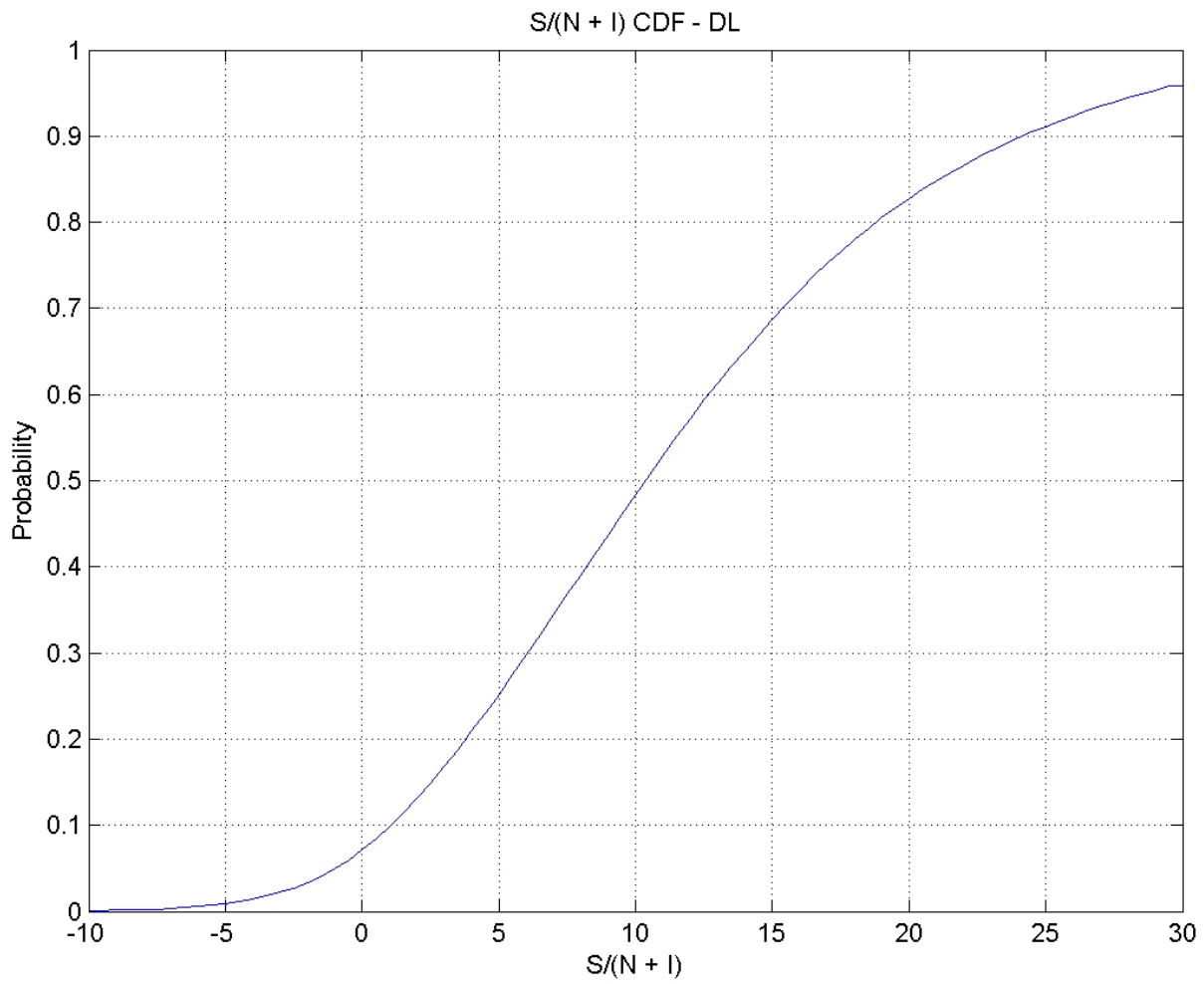


Figure 2: $S/(N+I)$ Cumulative Distribution Function (CDF) in the downlink - 2 Antenna STC, 3 sectors, reuse 1/3, ITU-B, 120Km/H

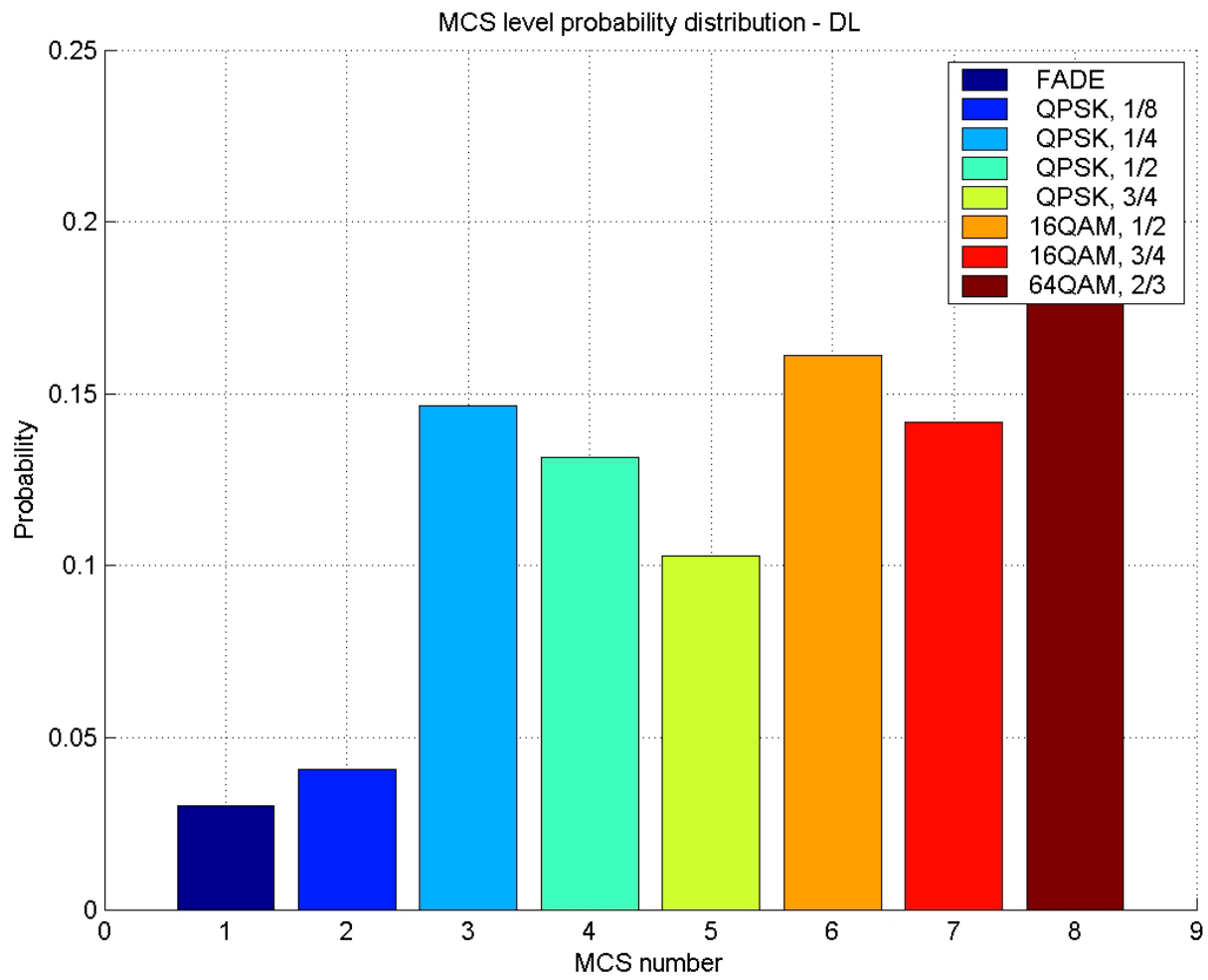


Figure 3: Modulation/Coding distribution in the downlink - 2 Antenna STC, 3 sectors, reuse 1/3, ITU-B, 120Km/H

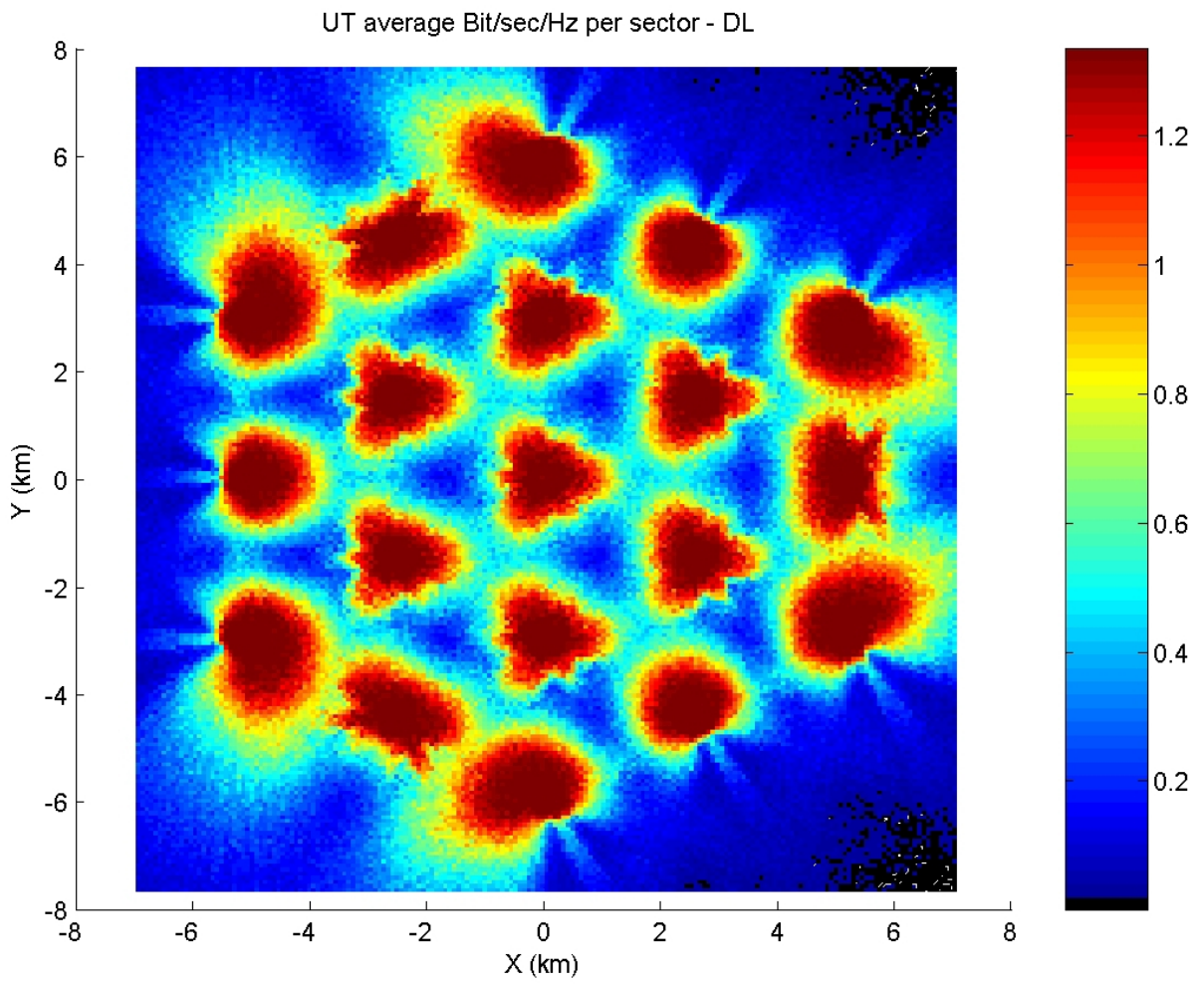


Figure 4: Average bit/sec/Hz per sector in the downlink - 2 Antenna STC, 3 sectors, reuse 1/3, ITU-B, 120Km/H

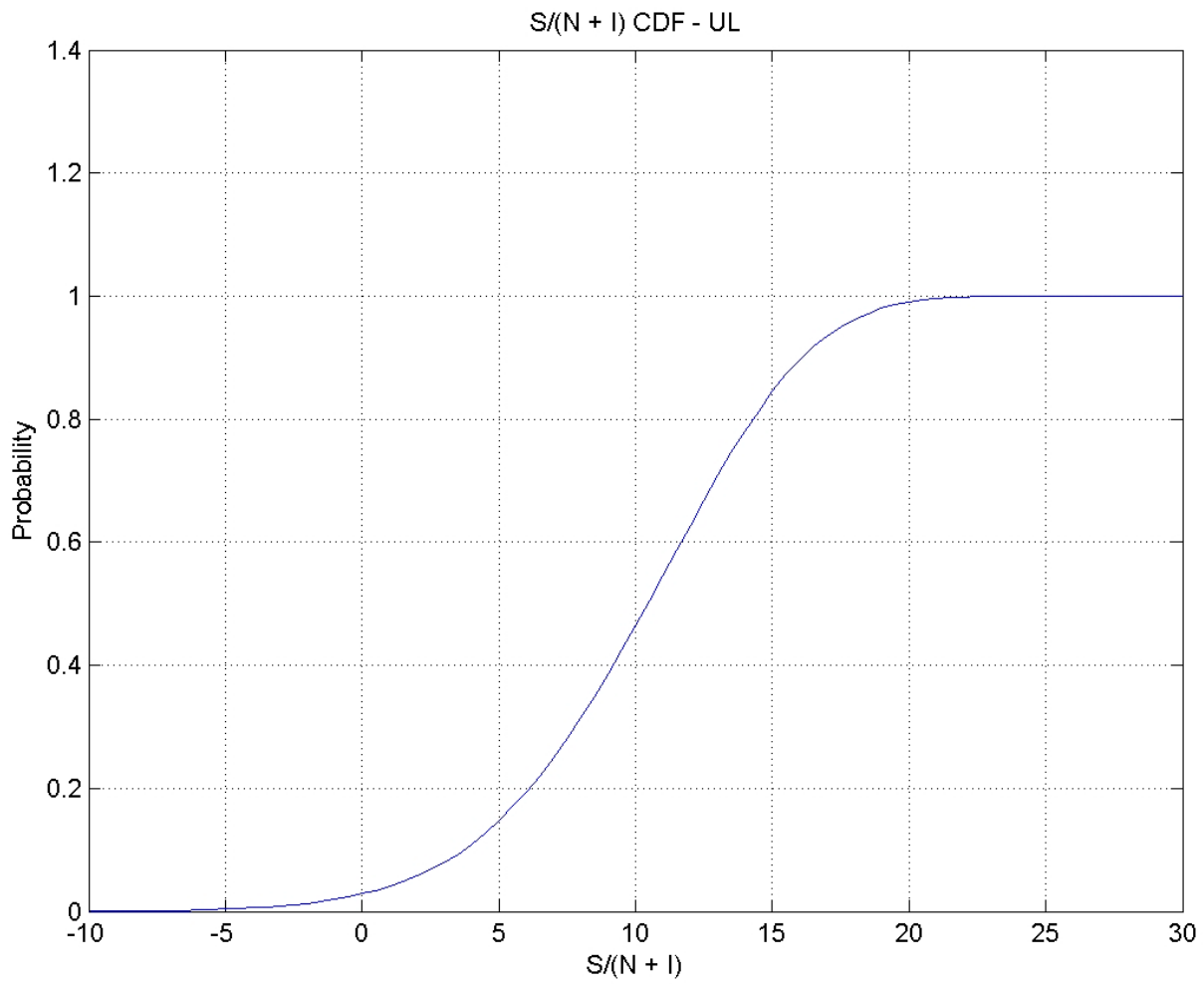


Figure 5: $S/(N+I)$ Cumulative Distribution Function (CDF) in the uplink - 2 Antenna STC, 3 sectors, reuse 1/3, ITU-B, 120Km/H

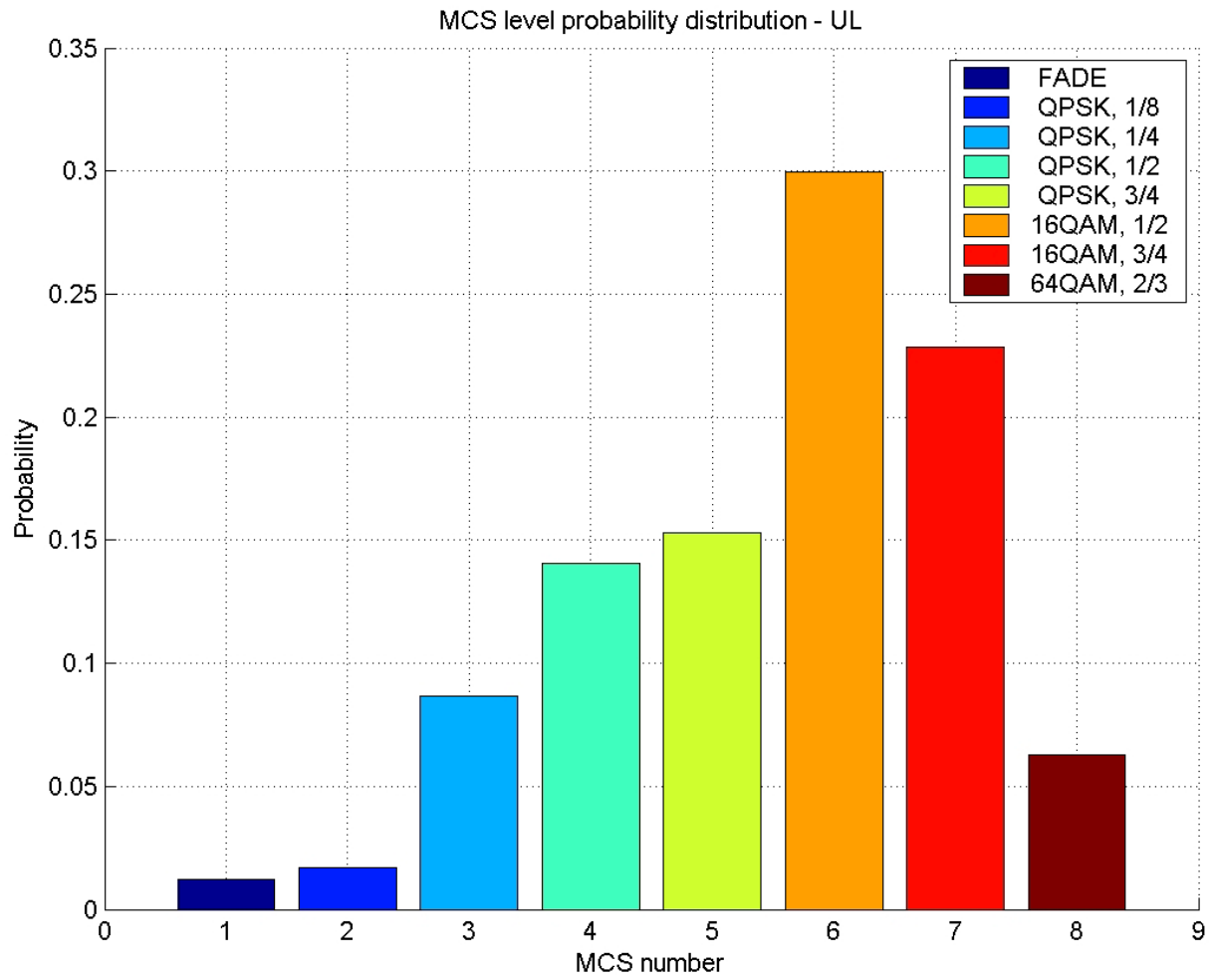


Figure 6: Modulation/Coding distribution in the uplink - 2 Antenna STC, 3 sectors, reuse 1/3, ITU-B, 120Km/H

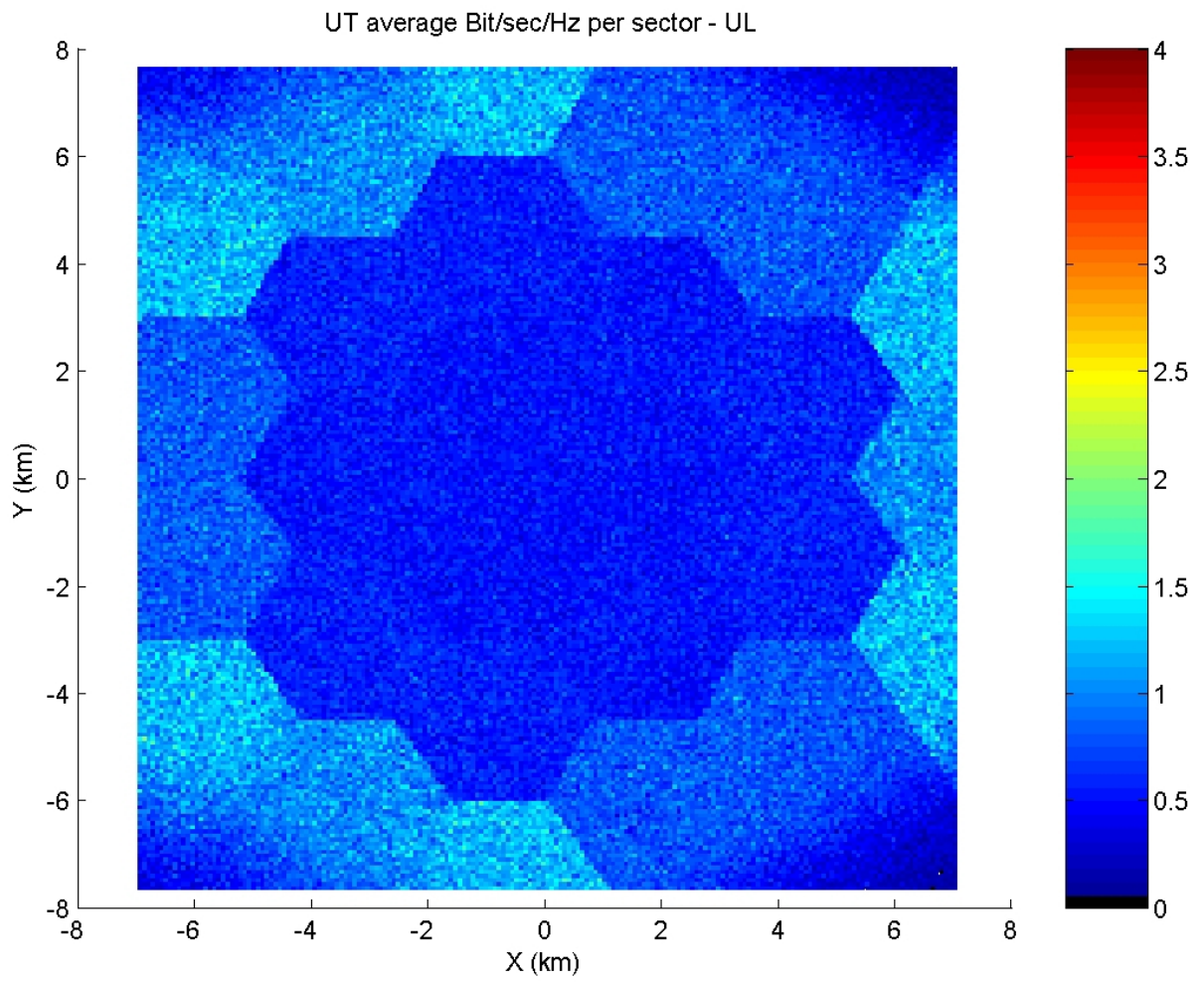


Figure 7: Average bit/sec/Hz per sector in the uplink - 2 Antenna STC, 3 sectors, reuse 1/3, ITU-B, 120K/H

Scenario: 2 Antenna STC, 6 sectors, reuse 1/2, ITU-B,120Km/H

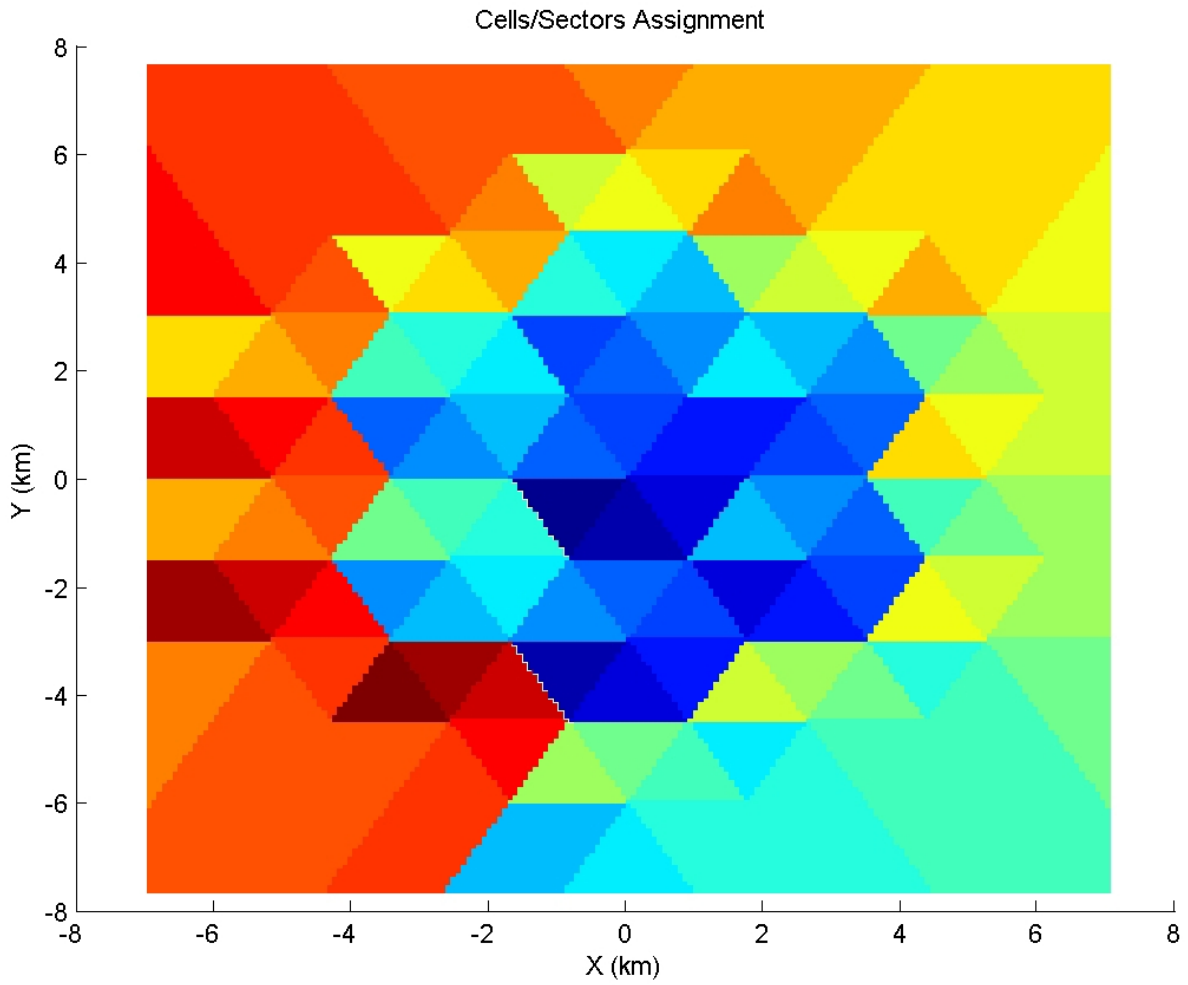


Figure 1: Cell/Sector Assignment - 2 Antenna STC, 6 sectors, reuse 1/2, ITU-B,120Km/H

Coverage Statistics:

- Average DL throughput = 0.85 Bit/Sec/Hz per sector
- DL Coverage

- **FADE - 5.72%**
- QPSK, 1/8 - 6.65%
- QPSK, 1/4 - 20.11%
- QPSK, 1/2 - 15.28%
- QPSK, 3/4 - 10.64%
- 16QAM, 1/2 - 13.97%
- 16QAM, 3/4 - 10.61%
- 64QAM, 2/3 - 17.01%

- Average UL throughput = 0.77 Bit/Sec/Hz per sector
- UL Coverage

- **FADE - 4.07%**
- QPSK, 1/8 - 4.09%
- QPSK, 1/4 - 16.62%
- QPSK, 1/2 - 18.91%
- QPSK, 3/4 - 16.23%
- 16QAM, 1/2 - 22.91%
- 16QAM, 3/4 - 13.75%
- 64QAM, 2/3 - 3.42%

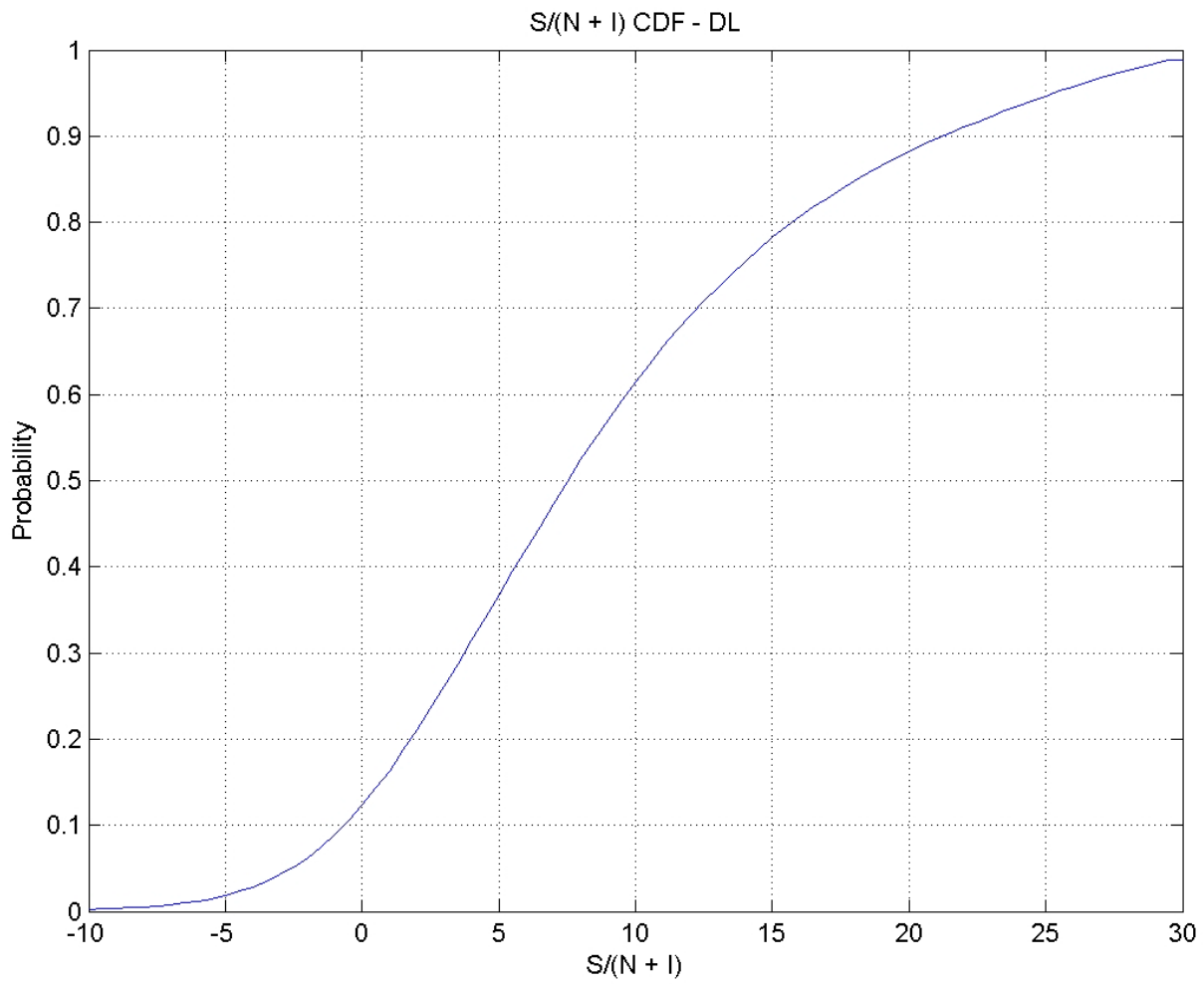


Figure 2: $S/(N+I)$ Cumulative Distribution Function (CDF) in the downlink - 2 Antenna STC, 6 sectors, reuse 1/2, ITU-B, 120Km/H

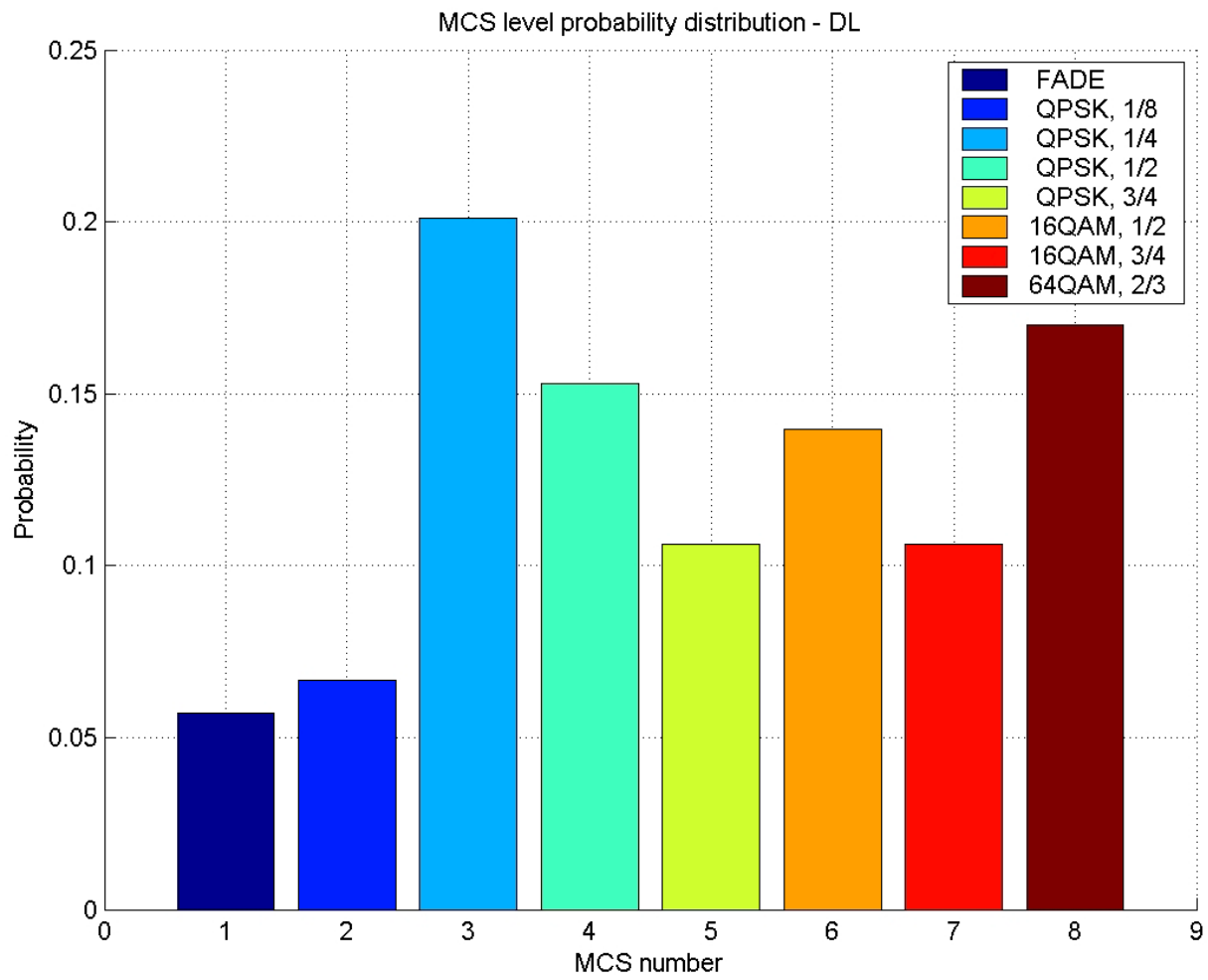


Figure 3: Modulation/Coding distribution in the downlink - 2 Antenna STC, 6 sectors, reuse 1/2, ITU-B, 120Km/H

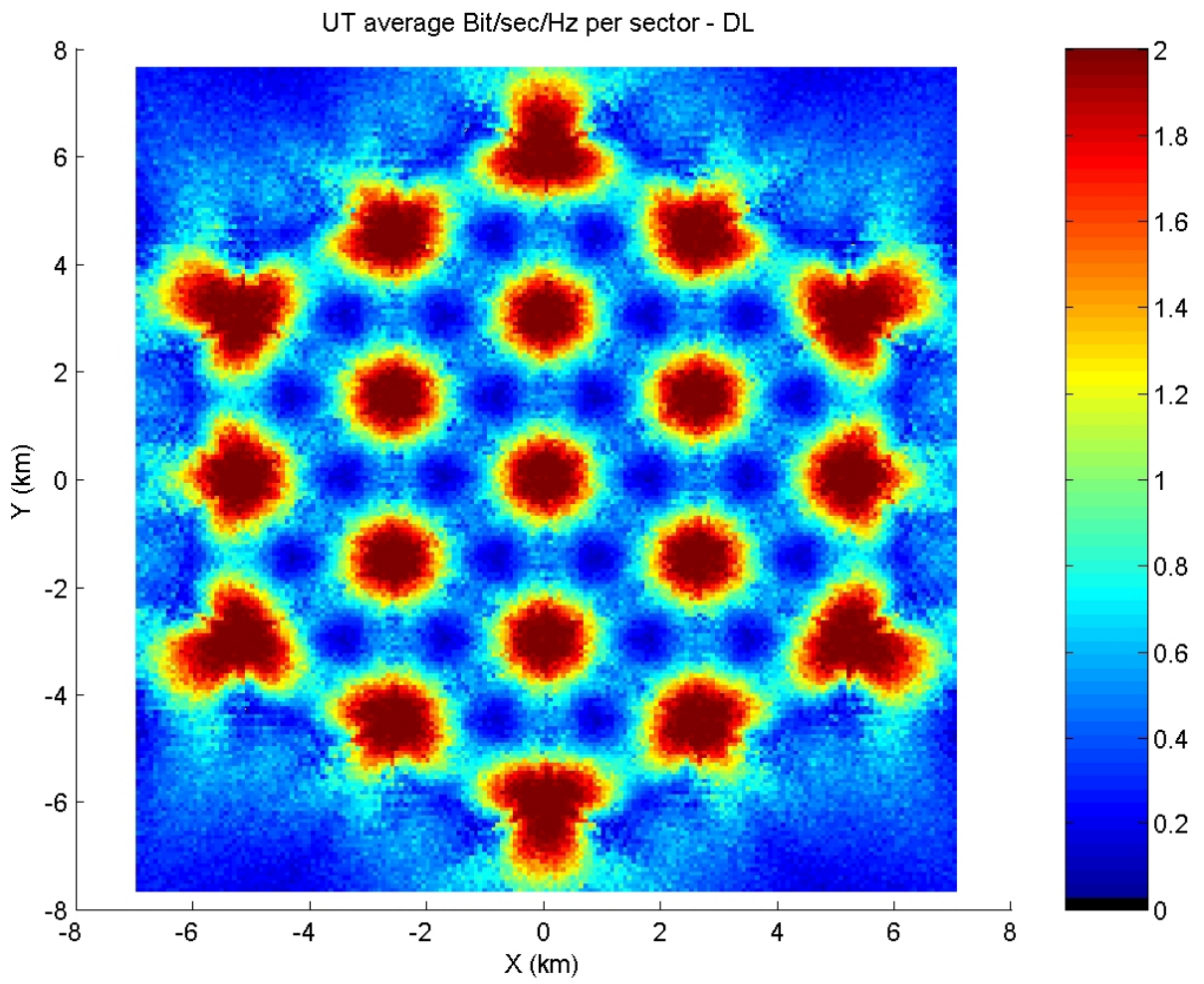


Figure 4: Average bit/sec/Hz per sector in the downlink - 2 Antenna STC, 6 sectors, reuse 1/2, ITU-B,120Km/H

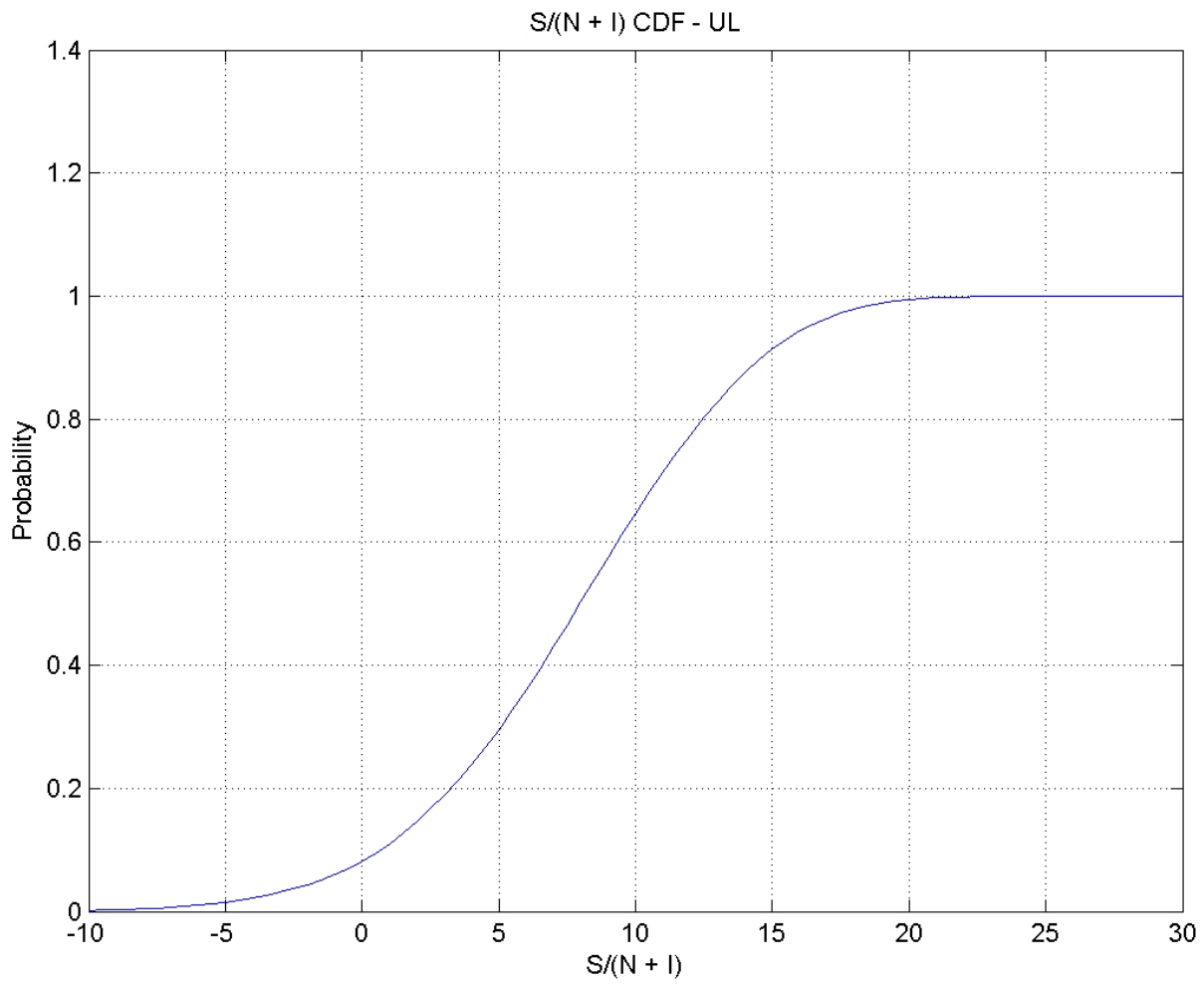


Figure 5: $S/(N+I)$ Cumulative Distribution Function (CDF) in the uplink - 2 Antenna STC, 6 sectors, reuse 1/2, ITU-B, 120Km/H

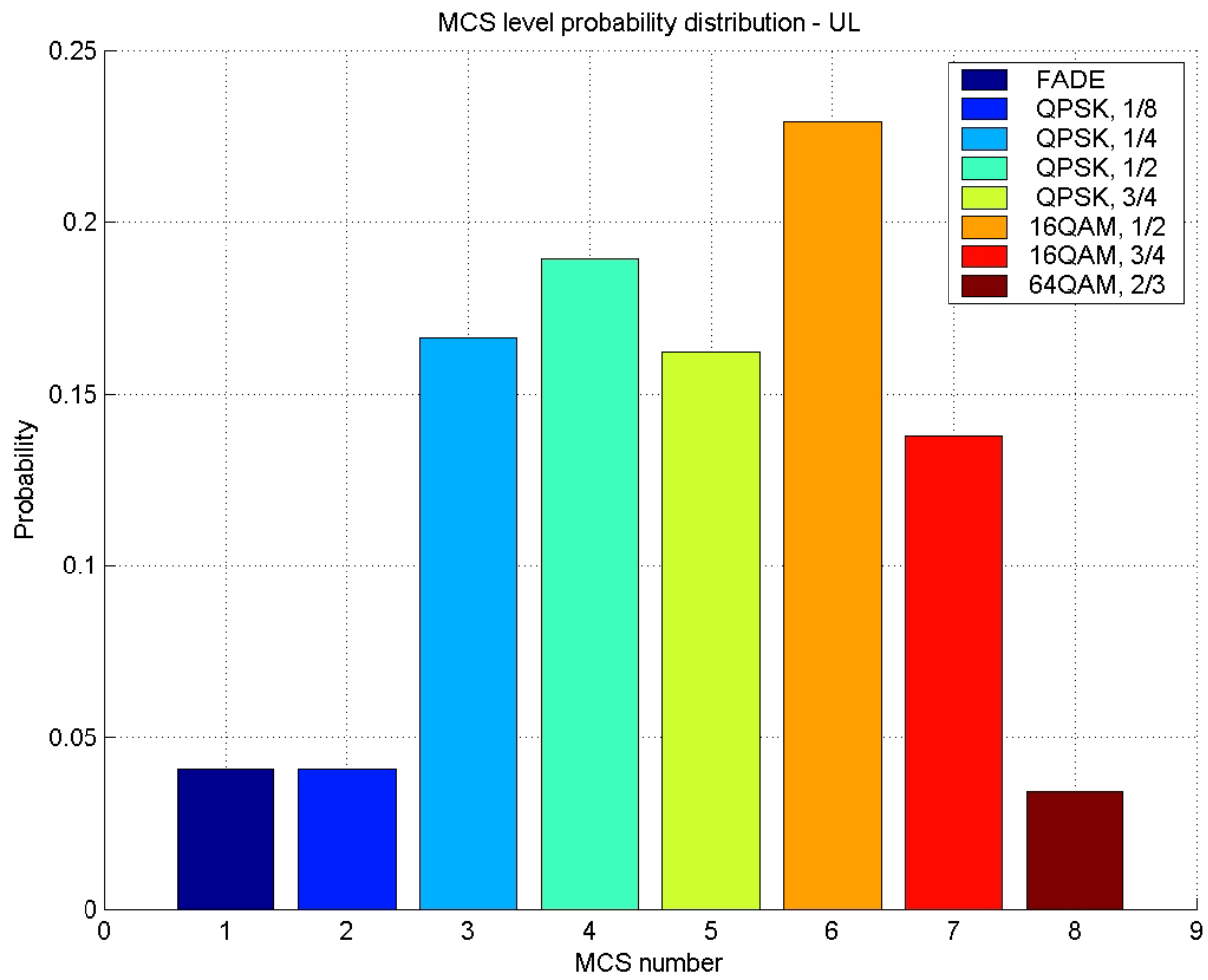


Figure 6: Modulation/Coding distribution in the uplink - 2 Antenna STC, 6 sectors, reuse 1/2, ITU-B, 120km/h

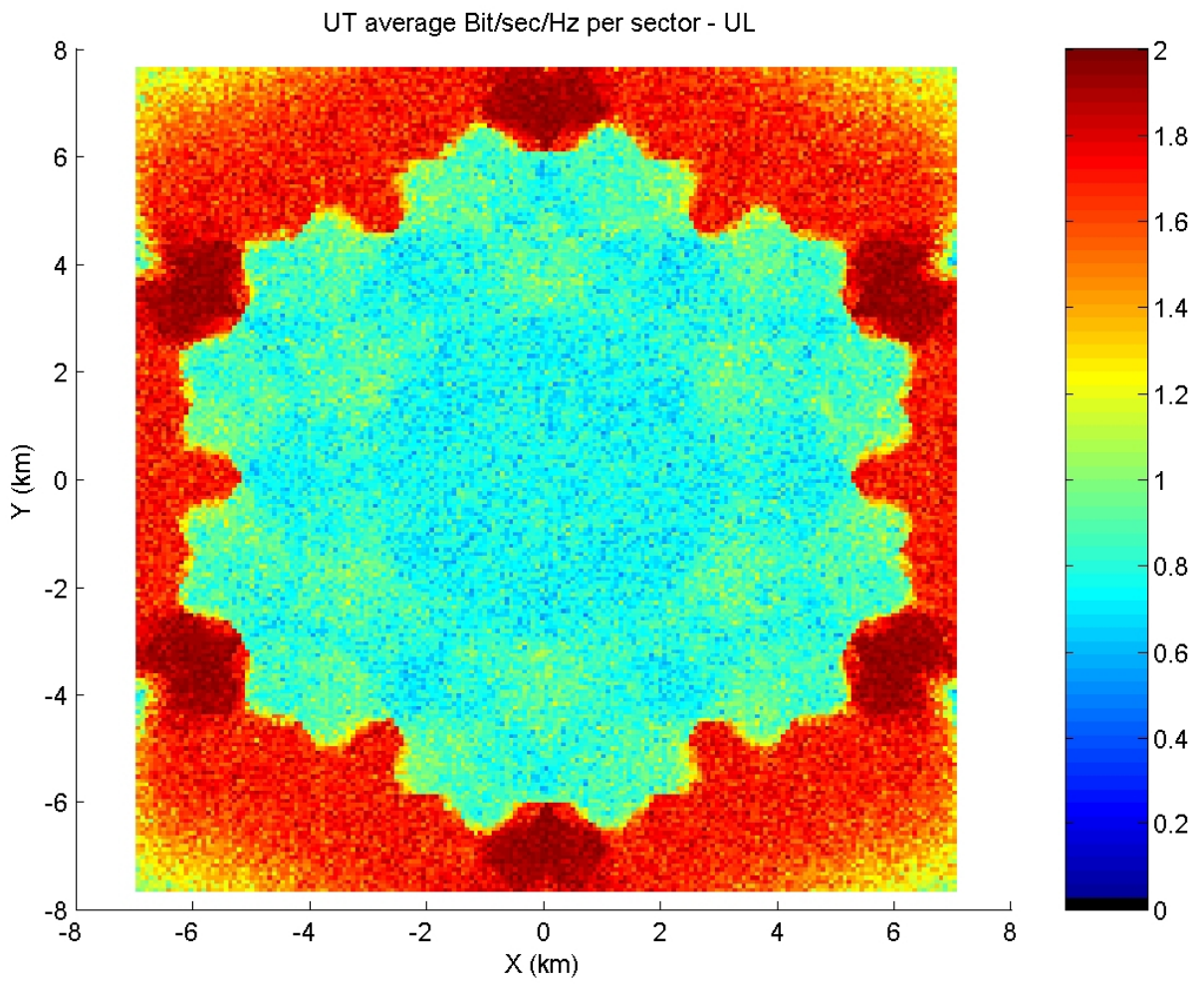


Figure 7: Average bit/sec/Hz per sector in the uplink - 2 Antenna STC, 6 sectors, reuse 1/2, ITU-B,120Km/H

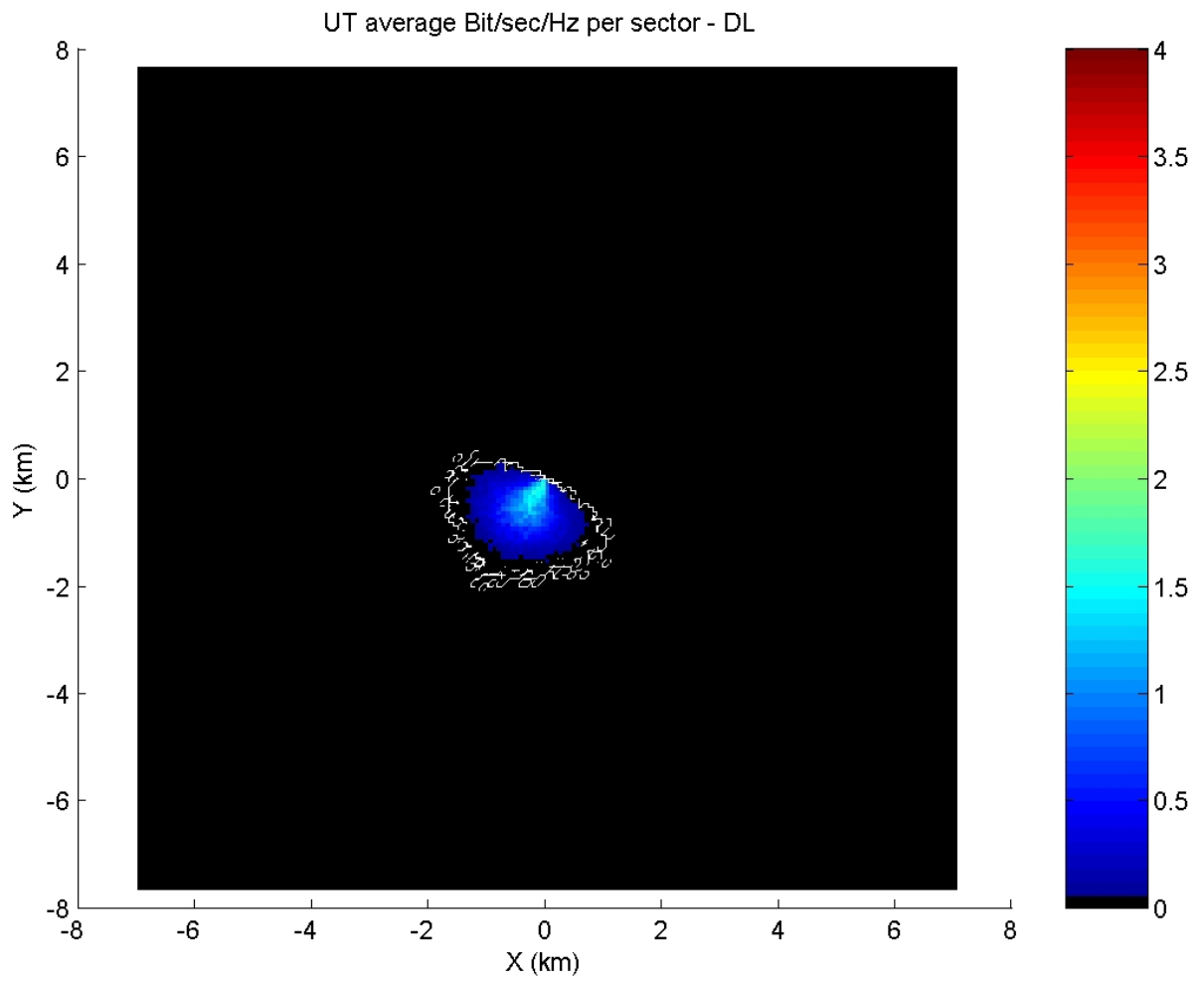


Figure 4: Average bit/sec/Hz per sector in the downlink - 3 Sectors, reuse 1, HO region, ITU-B, 120Km/H

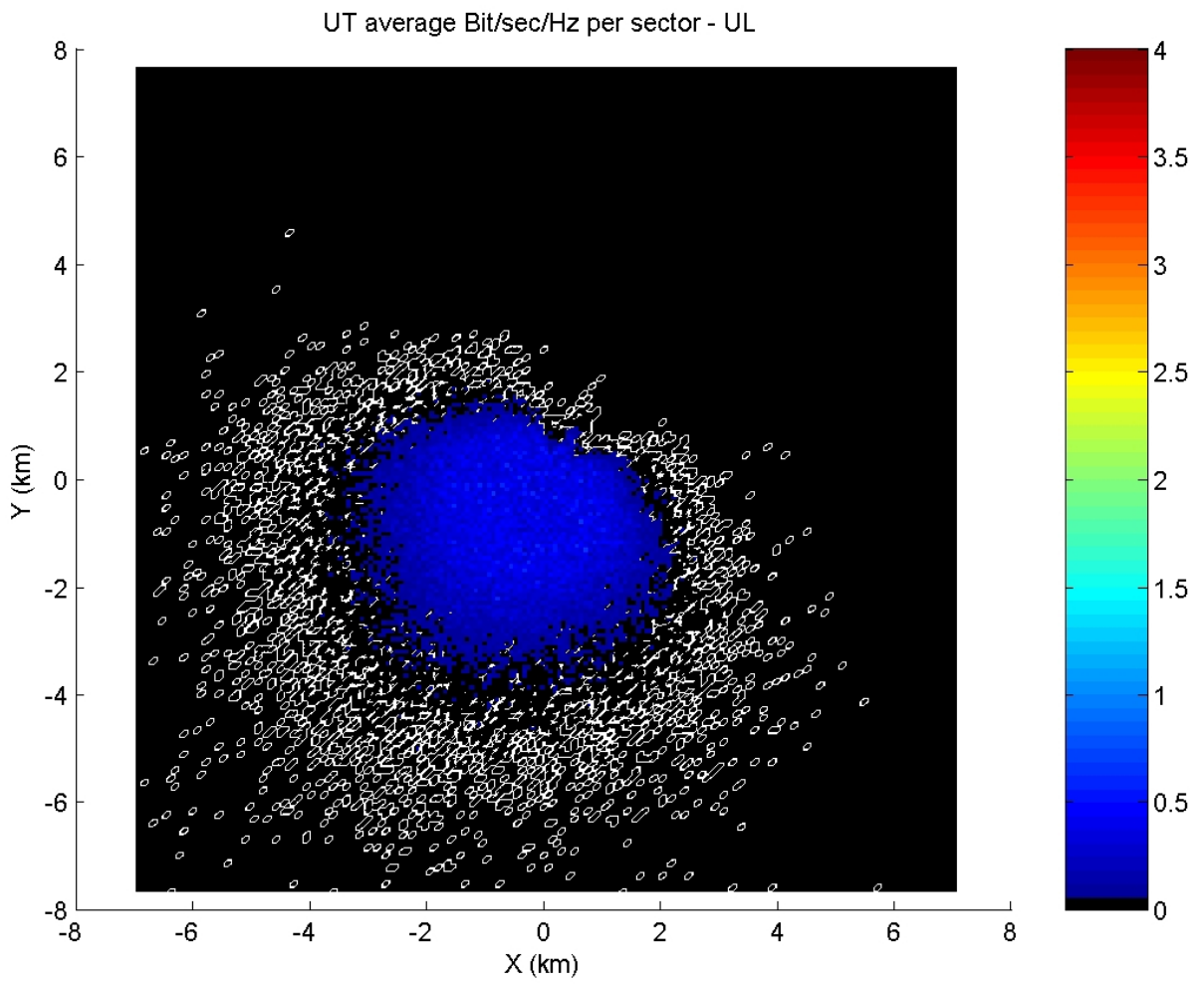


Figure 7: Average bit/sec/Hz per sector in the uplink - 3 Sectors, reuse 1, HO region, ITU-B,120Km/H

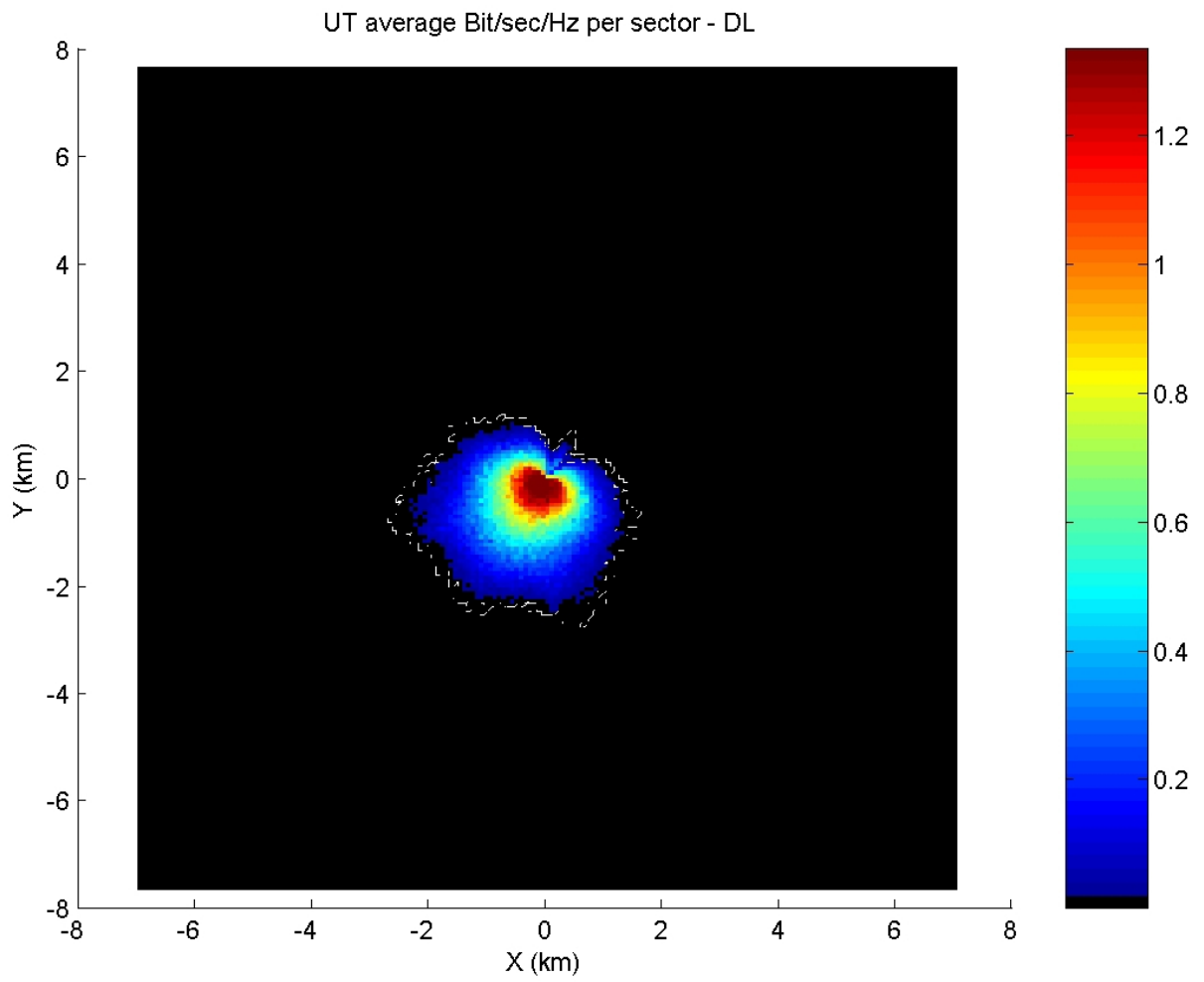


Figure 4: Average bit/sec/Hz per sector in the downlink - 3 Sectors, reuse 1/3, HO region, ITU-B,120Km/H

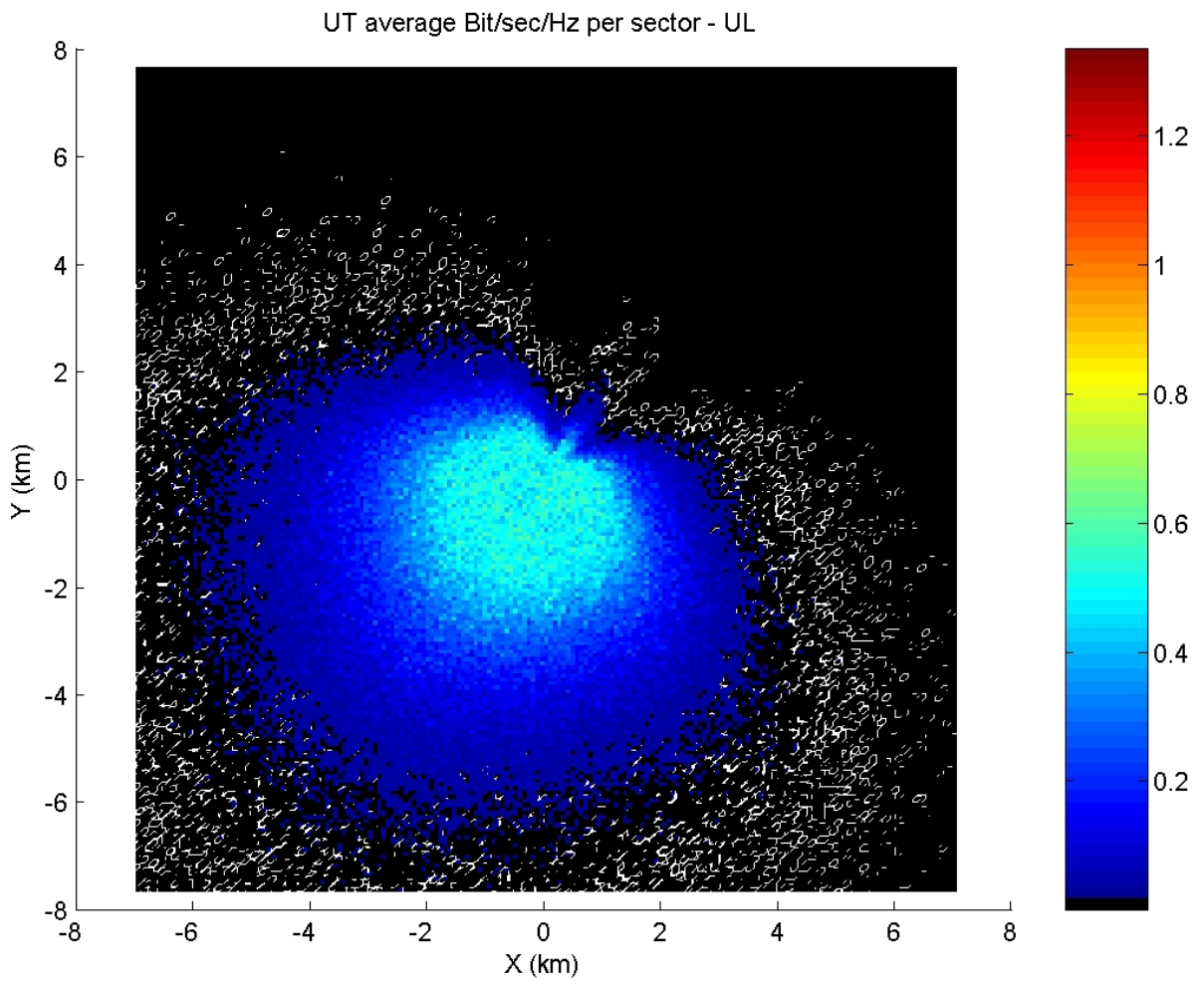


Figure 7: Average bit/sec/Hz per sector in the uplink - 3 Sectors, reuse 1/3, HO region, ITU-B,120Km/H

5 References

[1] RECOMMENDATION ITU-R M.1225, GUIDELINES FOR EVALUATION OF RADIO TRANSMISSION TECHNOLOGIES FOR IMT-2000