

**Automatic Modulation Classification in Mobile OFDM Systems
with Adaptive Modulation**

Von der Fakultät für Ingenieurwissenschaften
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Abstract

Adaptive modulation is an efficient way to combat the effects of deep fades in broadband orthogonal frequency division multiplexing (OFDM) systems with time-varying multipath propagation channels. Modulation schemes are adapted to the current channel state. Bandwidth efficient modulation schemes are applied on subcarriers with high channel quality, while robust modulation schemes or even no modulation are preferred for subcarriers in deep fades. The resulting benefit in terms of required transmit power was demonstrated for a fixed data rate in [1], where a gain of $5 \cdots 15$ dB was recorded for a BER of 10^{-3} over the OFDM system with a fixed modulation. Alternatively, adaptive modulation can also be used to improve the bandwidth efficiency. The advantage in terms of throughput was shown for a predefined quality of service in [2]. In literature, several algorithms have been proposed for adaptive modulation with different emphasis on bandwidth efficiency and implementation complexity [3], [4], [5]. In the thesis, the algorithm proposed in [6] is used.

A main drawback of adaptive modulation is that it requires information about the adapted modulation scheme at the receiver to enable demodulation. Traditionally, this information can be provided in forms of explicit signalling, which reduces the bandwidth efficiency due to the signalling overhead. In the thesis, proposals are developed to reduce this undesirable overhead. These proposals exploit the correlation properties inherently existing in the transmission channel in both time and frequency domain. These correlations lead to memory effects in the signalling source. State-dependent Huffman coding schemes are then applied to reduce the redundancy resulting from these memory effects [7].

This signalling overhead can be totally eliminated via automatic modulation classification (AMC). In the past, AMC was mainly of interest in military fields like threat analysis and electronic surveillance [8], where no prior knowledge about the used modulation scheme is available. Under such circumstance, maximum likelihood (ML) based AMC provides the optimum solution in the sense that the classification error probability is minimized. Nowadays, AMC is drawing more and more research interest also in civilian applications like systems with adaptive modulation, where certain cooperations are organized as in the system considered in this thesis. These cooperations provide certain prior information, which can be utilized to improve the classification reliability. Consequently, the ML based approach does not deliver the minimum error probability any more [9], [10] [11]. Investigations have to be conducted to verify how much the performance can be improved by incorporating this prior information into the AMC algorithm. As one focus in this thesis, a maximum a posteriori (MAP) based AMC is developed, which is potentially

able to minimize the classification error probability again. Another focus is to reduce the implementation complexity to enable the application of AMC in systems with high time requirements, e.g. real-time systems.

In the last part of the thesis, comparisons are performed between these two approaches, namely explicit signalling and signalling-free AMC, in terms of end-to-end packet error probability. To ensure a fair comparison, the net data rate is maintained as a constant in both operation modes.

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Contents

1	Introduction	1
1.1	Current state in modulation classification	1
1.2	Problem formulation	4
1.3	Structure of dissertation	7
2	Adaptive OFDM	8
2.1	Basics of OFDM	8
2.1.1	Generation of OFDM signals via IDFT	9
2.1.2	Cyclic prefix	10
2.1.3	Overview of advantages and disadvantages	12
2.2	Adaptive techniques in OFDM	13
2.2.1	Bit loading algorithm	14
2.2.2	Performance improvement in PER	16
3	Explicit signalling	18
3.1	In-band signalling strategy	18
3.2	Per-burst coding scheme	20
3.2.1	Trivial coding schemes	20
3.2.2	Huffman coding schemes	22
3.2.3	Frequency-domain correlation	24
3.3	Over-burst coding scheme	27
3.3.1	Time-domain correlation	28
3.4	Performance comparison	30
3.4.1	Implementation aspects	31
3.4.2	Simulation results	32
3.4.3	Conclusion	36
4	Automatic modulation classification	37
4.1	General framework	37
4.2	Likelihood-based AMC	40
4.2.1	Maximum-likelihood-based AMC	40
4.2.2	1-point approximation	42
4.2.3	Pure Euclidean distance approximation	45
4.2.4	4-points approximation	45
4.2.5	Bias effect and computational complexity	48

4.2.6	Simulation results	52
4.3	MAP-based AMC	56
4.3.1	Optimal MAP classifier	57
4.3.2	1-D approximated MAP classifier	59
4.3.3	2-D approximated MAP classifier	60
4.3.4	3-D approximated MAP classifier	62
4.3.5	Determination of the prior probabilities	63
4.3.6	Heuristic MAP classifier	64
4.3.7	MAC based on symmetric and bi-directional bit loading	67
4.3.8	Simulation results	69
4.4	Featured-based AMC	71
4.4.1	Higher order moment-based AMC	72
4.4.2	Higher order cumulant-based AMC	78
4.4.3	Simulation results	82
4.5	System-specific measures for performance improvement	83
4.5.1	Boundary conditions	84
4.5.2	Channel interpolation	88
4.5.3	Rotation of signal constellations	90
4.5.4	Simulation results	91
5	Comparison of signalling with automatic modulation classification	98
5.1	Parameter setting	98
5.1.1	Selection of signalling schemes	99
5.1.2	Determination of K_s	100
5.1.3	Determination of B_{DS}	101
5.1.4	Overview of K_s , B_{DS} and r_s	101
5.1.5	Selection of modulation classification schemes	102
5.2	Computer simulations	103
6	Conclusion	106
A	Simulation system	109
B	State-independent Huffman coding	114
C	State-dependent Huffman coding	116
C.1	Time-domain correlation	116
C.2	Frequency-domain correlation	117

D	Derivation of 4-point approximation	119
D.1	Approximation of the regular 4 QAM	119
D.2	Approximation of rotated 4 QAM	120
E	Derivation of approximation deviations	123
E.1	Deviations due to 4-P approximation	123
E.2	Deviations due to Euclidean distance based approximation	124
F	Higher-order moments and cumulants	126
F.1	Moment-based AMC	126
F.2	Cumulant-based AMC	126
G	3-D approximation	128
H	Further simulation results	129
I	Signalling versus automatic modulation classification	131
I.1	Further results for $K = 20$	131
I.2	Simulation results for $K = 10$	132