
Contents

Preface	xi
List of Acronyms	xiii
Notations	xvii
Introduction	xix
Chapter 1. Background	1
1.1. Introduction	1
1.2. Common operations and functions	1
1.2.1. Convolution	1
1.2.2. Scalar product	2
1.2.3. Dirac function, Dirac impulse and Kronecker's symbol	2
1.2.4. Step function	3
1.2.5. Rectangular function	3
1.3. Common transforms	3
1.3.1. Fourier transform	3
1.3.2. The z transform	6
1.4. Probability background	6
1.4.1. Discrete random variables	7
1.4.2. Continuous random variables	9
1.4.3. Jensen's inequality	9
1.4.4. Random signals	10
1.5. Background on digital signal processing	13

1.5.1. Sampling	13
1.5.2. Discrete, linear and time-invariant systems	14
1.5.3. Finite impulse response filters	17
1.5.4. Infinite impulse response filters	17
Chapter 2. Baseband Transmissions	19
2.1. Introduction	19
2.2. Line codes	20
2.2.1. Non-return to zero (NRZ) code	20
2.2.2. Unipolar return-to-zero (RZ) code	23
2.2.3. Bipolar return-to-zero (RZ) code	25
2.2.4. Manchester code	25
2.2.5. Alternate mark inversion code	26
2.2.6. Miller code	28
2.2.7. Non-return to zero inverted (NRZI)	31
2.2.8. Multi level transmit 3 (MLT-3) code	32
2.2.9. RLL(d,k) codes	33
2.2.10. M-ary NRZ code	35
2.3. Additive white Gaussian noise channel	36
2.4. Optimum reception on the additive white Gaussian noise channel	38
2.4.1. Introduction	38
2.4.2. Modulator's block diagram	39
2.4.3. Optimum receiver for the additive white Gaussian noise channel	44
2.4.4. Evaluation of the bit error rate for the binary NRZ signal on the additive white Gaussian noise channel	52
2.5. Nyquist criterion	60
2.5.1. Introduction	60
2.5.2. Transmission channel	61
2.5.3. Eye diagram	62
2.5.4. Nyquist criterion	63
2.5.5. Transmit and receive filters with matched filter	66
2.6. Conclusion	68

2.7. Exercises	69
2.7.1. Exercise 1: power spectrum density of several line codes	69
2.7.2. Exercise 2: Manchester code	70
2.7.3. Exercise 3: study of a magnetic recording system	70
2.7.4. Exercise 4: line code and erasure	72
2.7.5. Exercise 5: 4 levels NRZ modulation	73
2.7.6. Exercise 6: Gaussian transmit filter	74
2.7.7. Exercise 7: Nyquist criterion	75
2.7.8. Exercise 8: raised cosine filter	76
Chapter 3. Digital Modulations on Sine Waveforms	77
3.1. Introduction	77
3.2. Passband transmission and equivalent baseband chain	78
3.2.1. Narrowband signal	78
3.2.2. Filtering of a narrowband signal in a passband channel	82
3.2.3. Complex order of a second-order stationary random process	84
3.2.4. Synchronous detection	90
3.3. Linear digital modulations on sine waveforms	92
3.3.1. Main characteristics of linear digital modulations	92
3.3.2. Parameters of an M -symbols modulation	96
3.3.3. Amplitude shift keying	98
3.3.4. Phase shift keying	106
3.3.5. Quadrature amplitude modulations	113
3.3.6. Link between $\frac{E_b}{N_0}$ and signal-to-noise ratio depending on the power values	119
3.3.7. Power spectrum density of regular modulations	120
3.3.8. Conclusion	121
3.4. Frequency shift keying	122
3.4.1. Definitions	122
3.4.2. Discontinuous-phase FSK	124
3.4.3. Continuous-phase FSK	126
3.4.4. Demodulation	126
3.4.5. GMSK modulation	130
3.4.6. Performances	132
3.5. Conclusion	135

3.6. Exercises	135
3.6.1. Exercise 1: constellations of 8-QAM	135
3.6.2. Exercise 2: irregular ASK modulation	136
3.6.3. Exercise 3: comparison of two PSK	137
3.6.4. Exercise 4: comparison of QAM and PSK modulations	137
3.6.5. Exercise 5: comparison of 8-PSK and 8-QAM modulations	138
3.6.6. Exercise 6: comparison of 2-FSK and 2-ASK modulations	139
3.6.7. Exercise 7: comparison of 16-QAM and 16-FSK	140
Chapter 4. Synchronization and Equalization	141
4.1. Introduction	141
4.2. Synchronization	142
4.2.1. Frequency shift correction	144
4.2.2. Time synchronization	150
4.2.3. Channel estimate with training sequence	153
4.2.4. Cramer–Rao’s bound	154
4.3. Equalization	157
4.3.1. Channel generating distortions	158
4.3.2. Discrete representation of a channel with inter-symbol interference and preprocessing	159
4.3.3. Linear equalization	162
4.3.4. Decision-feedback equalization	177
4.3.5. Maximum likelihood sequence estimator	180
4.4. Conclusion	186
4.5. Exercises	187
4.5.1. Exercise 1: estimation of a constant signal from noisy observations	187
4.5.2. Exercise 2: frequency shift correction	188
4.5.3. Exercise 3: zero-forcing equalization	188
4.5.4. Exercise 4: MMSE equalization	189
4.5.5. Exercise 5: MMSE-DFE equalization	190
4.5.6. Exercise 6: MLSE equalization with one shift register	190
4.5.7. Exercise 7: MLSE equalization with two shift registers	190

Chapter 5. Multi-carrier Modulations	193
5.1. Introduction	193
5.2. General principles of multi-carrier modulation	196
5.2.1. Parallel transmission on subcarriers	196
5.2.2. Non-overlapping multi-carrier modulations: FMT	197
5.2.3. Overlapping multi-carrier modulations	198
5.2.4. Chapter's structure	199
5.3. OFDM	199
5.3.1. Transmission and reception in OFDM	201
5.3.2. Cyclic prefix principle	202
5.3.3. Optimum power allocation in OFDM	209
5.3.4. PAPR	215
5.3.5. Sensitivity to asynchronicity	218
5.3.6. OFDM synchronization techniques	219
5.4. FBMC/OQAM	225
5.4.1. Principles of continuous-time FBMC/OQAM	225
5.4.2. Discrete-time notations for FBMC/OQAM	231
5.4.3. Prototype filter	233
5.5. Conclusion	236
5.6. Exercises	236
5.6.1. Exercise 1	236
5.6.2. Exercise 2	237
Chapter 6. Coded Modulations	239
6.1. Lattices	240
6.1.1. Definitions	240
6.1.2. Group properties of a lattice	245
6.1.3. Lattice classification	248
6.1.4. Lattice performances on the additive white Gaussian noise channel	251
6.2. Block-coded modulations	255
6.2.1. Main algebraic constructions of lattices	256
6.2.2. Construction of block-coded modulations	259
6.3. Trellis-coded modulations	270
6.3.1. Construction of trellis-coded modulations	271
6.3.2. Decoding of trellis-coded modulations	275
6.4. Conclusion	276

Appendices	277
Appendix A	279
Appendix B	285
Bibliography	291
Index	297
Summary of Volume 1	299