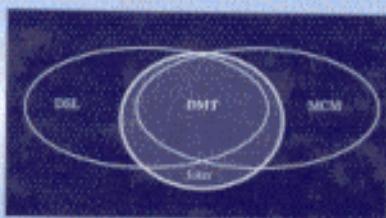


ADSL, VDSL, and Multicarrier Modulation



Suranaree University of Technology



31051000606380

John A. C. Bingham

Wiley Series in Telecommunications and Signal Processing
John G. Proakis, Series Editor

CONTENTS

Preface	xv
CHAPTER 1 Introduction	1
1.1 Arrangement of This Book	2
1.2 History (Ongoing) of Data on the DSL	2
1.3 History of Multicarrier Modulation	4
1.4 MCM (DMT) and DSL	5
1.5 ADSL "Lite"	6
1.6 Some Housekeeping Details	7
1.6.1 Units of Measurement	7
1.6.2 References	7
CHAPTER 2 ADSL Network Architecture, Protocols, and Equipment	9
<i>A. J. Weissberger</i>	
2.1 ADSL Advantages and Applications	9
2.2 ADSL Transport Modes: STM or ATM?	10
2.3 ATM End-to-End Network Architectures and Protocol Stacks	11
2.3.1 New Equipment Needed for ADSL	13
2.4 Mapping Digital Information to ADSL User Data	14
2.4.1 Premises Architecture and DTE-to-DCE Interface	14
2.4.2 Traffic Shaping	15
2.4.3 Single or Dual Latency at the ATM Layer	15
2.5 Unique ADSL Requirements for ATM	16
2.6 ADSL Network Management and Management Information Busses	17
2.7 Observations	19

CHAPTER 3 The DSL as a Medium for High-Speed Data	21
3.1 Make-up of a Loop	21
3.1.1 Length of the Loop	22
3.1.2 Balance	23
3.1.3 Wire Gauge and Gauge Changes	23
3.1.4 Bridge Taps	24
3.1.5 Loading Coils	25
3.1.6 The Drop Wire	25
3.2 Ladder Model of an Unshielded Twisted Pair	26
3.2.1 Is a UTP a Minimum-Phase Network?	29
3.3 Distributed <i>RLGC</i> Parameters	30
3.3.1 <i>R</i> and <i>L</i> , and <i>G</i> and <i>C</i> as Hilbert-Transform Pairs	31
3.3.2 A Recommendation	33
3.4 Transformer Coupling and dc Blocking	34
3.5 Chain Matrix Characterization	34
3.5.1 In-line Sections	34
3.5.2 Bridge Taps	35
3.5.3 High-Pass Filters	35
3.5.4 The End-to-End Loop	36
3.5.5 MATLAB Program for Chain Matrix-Based Analysis	36
3.5.6 Frequency and Depth of the Notch Caused by a Simple Bridge Tap	36
3.5.7 Calculated Versus Measured Responses: A Cautionary Tale	38
3.6 Crosstalk	38
3.6.1 NEXT	40
3.6.2 FEXT	42
3.6.3 Measurements and Statistical Models of Crosstalk	45
3.6.4 Crosstalk from Mixed Sources	48
3.6.5 Modeling and Simulation of Crosstalk	50
3.6.6 Discussion of Terminology, and Comparison of NEXT and FEXT	55
3.7 Radio-Frequency Interference	56
CHAPTER 4 DSL Systems: Capacity, Duplexing, Spectral Compatibility, and System Management	59
4.1 Capacity	59
4.1.1 Modulation and Demodulation	59
4.1.2 Coding	60
4.1.3 Margin	60

4.1.4	Error Rate	61
4.1.5	The DFE Bound	61
4.2	Duplexing Methods	62
4.2.1	Terminology	62
4.2.2	Echo Canceling	62
4.2.3	Frequency-Division Duplexing	63
4.2.4	EC/FDD	63
4.2.5	Time-Division Duplexing	64
4.3	Capacity Revisited	65
4.4	A Decision: EC or Not?	66
4.5	Spectral Compatibility	68
4.6	System Management	69
4.6.1	Local Exchange Carriers: Incumbent and Competitive	70
4.6.2	Mix of Data Rates and Rate Adaptation	74
4.6.3	PSD Controls	74
4.6.4	Enabling or Disabling Options	75
4.6.5	Binder-Group Management	75
4.6.6	Rates, Ranges, or Numbers of Customers?	77
4.7	Spectral Management Standard: Status, Fall 1999	78

CHAPTER 5 Fundamentals of Multicarrier Modulation 79

5.1	Block Diagram	79
5.2	Channel Measurement	81
5.3	Adaptive Bit Loading: Seeking the “Shannongri-la” of Data Transmission	82
5.3.1	Adaptive Loading with a PSD Limitation	82
5.3.2	Adaptive Loading with a Total Power Constraint	84
5.4	SCM/MCM Duality	85
5.5	Distortion, Efficiency, and Latency	86
5.6	The Peak/Average Ratio Problem	87
5.6.1	Clipping	88

CHAPTER 6 DFT-Based MCM (MQASK, OFDM, DMT) 91

6.1	Guard Period	93
6.1.1	Length of the Guard Period	95
6.2	Effects of Channel Distortion	95
6.2.1	Total Distortion: Signal/Total Distortion Ratio	97
6.2.2	Case of Both Post- and Precursors	98
6.2.3	Distortion on Individual Subchannels: SDR(j)	98

6.3	The Sidelobe Problem	99
6.3.1	Noise Smearing and Resultant Enhancement	99
6.3.2	Noise Enhancement from Linear Equalization	101
6.3.3	Reducing Noise Enhancement	103
6.3.4	Band Limiting	105
6.4	Reducing the Sidelobes: Shaped Cyclic Prefix	105
6.4.1	Sensitivity to Channel Distortion	107
6.4.2	Advantages and Disadvantages of the Four Methods of Using a Shaped Cyclic Prefix	108
6.5	Dummy Tones to Reduce Out-of-Band Power?	109

CHAPTER 7 Other Types of MCM 111

7.1	Frequency-Domain Spreading	112
7.1.1	Frequency-Domain Partial Response	112
7.1.2	Polynomial Cancellation Coding	114
7.2	Filtering	115
7.3	Time-Domain Shaping	116
7.3.1	Whole Pulse Shaping with Synchronized Inputs	116
7.3.2	Whole Pulse Shaping with Staggered Inputs: SMCM	116
7.3.3	PCC with Time-Domain Overlap	119
7.4	Discrete Wavelet Multitone (<i>by Aware Inc.</i>)	119
7.4.1	Performance Evaluations and Comparisons	129

CHAPTER 8 Implementation of DMT: ADSL 133

8.1	Overall System	133
8.1.1	The Design and Implementation Problem	134
8.1.2	Numerical Details	136
8.2	Transmitter	137
8.2.1	Transport of the Network Timing Reference	137
8.2.2	Input Multiplexer and Latency (Interleave) Path Assignment	138
8.2.3	Scrambler	138
8.2.4	Reed-Solomon Forward Error Correction	139
8.2.5	Interleaving	139
8.2.6	Tone Ordering	142
8.2.7	Trellis Code Modulation	142
8.2.8	Pilot Tone	143
8.2.9	Inverse Discrete Fourier Transform	143
8.2.10	Cyclic Prefix	143
8.2.11	PAR Reduction	143

8.2.12	Digital-to-Analog Converter	154
8.2.13	Line Drivers	159
8.3	Four-Wire/Two-Wire Conversion and Transmit/Receive Separation	160
8.3.1	Line-Coupling Transformer	160
8.3.2	4W/2W Hybrid	160
8.3.3	Echo Canceler?	163
8.3.4	FDD Filters	164
8.4	Receiver	166
8.4.1	Analog Equalizer?	167
8.4.2	Analog-to-Digital Converter	168
8.4.3	Timing Recovery and Loop Timing	168
8.4.4	Time-Domain Equalizers	171
8.4.5	FFT	176
8.4.6	Frequency-Domain Equalizer	176
8.4.7	Trellis Decoder (Viterbi Decoder)	176
8.4.8	De-interleaver	177
8.4.9	Reed-Solomon Decoder	177
8.4.10	Descrambler	177
8.5	Algorithms (Part Transmitter and Part Receiver)	177
8.5.1	Channel Measurement	177
8.5.2	Bit Loading	177
8.5.3	Bit Rate Maintenance (Bit Swap)	177
8.5.4	Dynamic Rate Adaptation	178
8.5.5	Unfinished Business: Bit Rate Assurance	179

CHAPTER 9 Coexistence of ADSL with Other Services

181

9.1	Coexistence with Voice-Band Services	181
9.1.1	Transient Protection for the ATU	183
9.1.2	Isolating the Voice Band from the (Low) Input Impedance of the ATU	184
9.1.3	Maintaining Voice-Band Quality	184
9.1.4	One Solution to the Impedance Problem: Generalized Immittance Converters	188
9.1.5	A Partial Solution: Custom Design by Optimization	191
9.1.6	Simplified (Dispersed and Proliferated) Low-Pass Filters	191
9.2	G.992 Annex B: Coexistence with Echo-Canceled ISDN	195
9.3	G.992 Annex C: Coexistence with TDD ISDN	195
9.3.1	Synchronizing TDD ISDN and ADSL	197
9.3.2	Band Assignments and FFT Sizes	198

9.3.3 Separate Quads for ISDN and ADSL	199
9.3.4 ULFEXT from Close-in ISDN Modems	199
CHAPTER 10 VDSL: Requirements and Implementation	201
10.1 System Requirements and Consequences Thereof	202
10.1.1 Services, Ranges, and Rates	203
10.1.2 Transmit PSDs and Bit Loading	203
10.1.3 Coexistence with ADSL	204
10.1.4 Coexistence with Echo-Canceled BRI	207
10.1.5 Compatibility with Amateur (Ham) and AM Radio	208
10.1.6 The Network Termination	208
10.2 Duplexing	209
10.2.1 Echo Cancellation?	209
10.2.2 FDD or TDD?	210
10.2.3 Mixed Services	210
10.3 FDD	210
10.3.1 Mixture of Symmetric and Asymmetric Services	211
10.4 Zipper	211
10.4.1 Basic Zipper/DD System	212
10.4.2 Analog Front End and ADC	216
10.4.3 Echoes and NEXT	219
10.4.4 Mixture of Symmetric and Asymmetric Services	220
10.4.5 Coexistence with ADSL	220
10.4.6 Coexistence with TDD BRI	221
10.4.7 Bit Loading	221
10.4.8 Equalization	221
10.5 Synchronized DMT	221
10.5.1 Basic SDMT System Compatible with TDD BRI	222
10.5.2 Analog Front End and ADC	224
10.5.3 Synchronization	224
10.6 Dealing with RFI from Ham and AM Radio	227
10.6.1 Front-End Analog Cancellation	228
10.6.2 Shaped Windowing	229
10.6.3 Digital Filtering	229
10.6.4 Digital Cancellation	230
10.6.5 Unfinished Business	233
10.7 Comparison Among FDD, Zipper, and SDMT	233
10.7.1 Efficiency	234
10.7.2 Latency	234

10.7.3	Mixture of Symmetric and Asymmetric Services and Coexistence with ADSL	234
10.7.4	RFI Egress Control	235
10.7.5	Analog RFI Cancellation	235
10.7.6	Digital RFI Cancellation	235
10.7.7	AFE Performance	235
10.7.8	Complexity: AFE and ADC	235
10.7.9	Complexity: FFTs	235
10.7.10	Complexity: Equalizer	236
10.7.11	Complexity: Bit Loading Algorithm	236
10.7.12	Power Consumption	236
10.7.13	Synchronization	236
10.7.14	Summary	237
10.8	A Last-Minute Personal Footnote	237
10.8.1	Duplexing	237
10.8.2	Modulation	238

CHAPTER 11 Future Improvements**239**

11.1	Frequency-Domain Partial Response	239
11.1.1	FDPR in the Transmitter	239
11.1.2	FDPR in the Receiver	240
11.1.3	Filterless FDD	240
11.1.4	Unfinished Business: Coding for FDPR to Retrieve “Lost” 3 dB	241
11.2	Equalization	241
11.2.1	TEQ	241
11.2.2	FEQ	243
11.2.3	TEQ or FEQ?	246
11.3	Echo Cancellation	247
11.4	Front-End Crosstalk Cancellation	249
11.5	Digital NEXT Cancellation	250
11.6	Cancellation of RF and Other Interference	250
11.6.1	Unfinished Business	252
11.6.2	Grand Finale	252

APPENDIX A Matlab Programs for xDSL Analysis**253**

A.1	Frequency-Domain Analysis: Response and Input Impedances	253
A.2	Loop Capacity	255

APPENDIX B Organizations, Recommendations, and Standards	257
B.1 International Telecommunications Union	257
B.2 American National Standards Institute	258
B.3 European Telecommunications Standards Institute	258
B.4 ATM Forum	258
B.5 ADSL Forum	258
APPENDIX C Efficient Hardware Implementations of FFT Engines	259
<i>Mitra Nasserbakht</i>	
C.1 Overview	259
C.2 Fast Fourier Transform	259
C.2.1 Radix-2 FFT Computation	260
C.2.2 Radix-4 FFT Computation	261
C.2.3 Decimation in Time	262
C.2.4 Decimation in Frequency	262
C.3 Architectural Considerations	262
C.3.1 Number Representation Scheme	263
C.3.2 Memory Subsystem	265
C.3.3 Scrambling and Unscrambling of Data	268
C.3.4 Twiddle Factor Generation	268
C.4 Representative FFT Engine Implementation	269
C.4.1 Data Format	269
C.4.2 FFT System Top-Level Architecture	270
C.4.3 Processor Pipeline Stages	271
C.4.4 Dedicated Storage Elements	273
References	275
Index	285