
INDEX

A

- A posteriori* log-likelihood ratio (LLR), 315
 - A posteriori* probabilities (APPs), 305
 - A priori* probabilities, 305
 - ACM (approximate conditional mean) filter, 397–400
 - simulation examples, 399–400
 - ACM interpolator, 403–404
 - Adaptive array processing in TDMA systems, 226–239
 - extension to dispersive channels, 237–239
 - simulation examples, 238–239
 - linear MMSE combining, 228–230
 - signal model, 226–228
 - subspace-based training algorithm, 230–237
 - Adaptive group-blind linear multiuser detection, 151–155
 - simulation examples, 153–155
 - Adaptive linear MMSE NBI
 - suppression, 429–431
 - simulation examples, 430–431
 - Adaptive multiuser detection
 - scenarios, 49–58
 - Adaptive nonlinear block interpolator, 404–406
 - Adaptive nonlinear predictor, 400–403
 - simulation examples, 402–403
 - Adaptive processing, 449
 - Adaptive receiver in fading Gaussian noise channels:
 - coded case, 541–544
 - simulation examples, 544
 - uncoded case, 531–534
 - Adaptive receiver structures, 82–86
 - in multipath channels, 82–86
 - simulation example, 85–86
 - Adaptive receivers in fading impulsive noise channels, 544–548
 - simulation examples, 547–548
 - Adaptive SMC (sequential Monte Carlo) receivers for flat-fading channels, 523–548
 - adaptive receiver in fading Gaussian noise channels:
 - coded case, 541–544
 - uncoded case, 531–534
 - adaptive receivers in fading impulsive noise channels, 544–548
 - simulation examples, 547–548
 - delayed estimation, 534–541
 - delayed-sample method, 536–538
 - delayed-weight method, 534–536
 - simulation examples, 539–541
 - system description, 527–530
- Adaptive space-time multiuser detection in multipath CDMA, 287–301
 - blind adaptive channel estimation, 295–301
 - discrete-time channel model, 295–297
 - problem, 297–299
 - simulation results, 299–301

- blind MMSE space-time multiuser detection, 294
 - signal model, 287–294
 - Adaptive space-time multiuser detection in synchronous CDMA, 265–287
 - blind adaptive implementations, 281–287
 - adaptive blind linear space-time multiuser detection, 285–287
 - batch blind linear space-time multiuser detection, 284–285
 - one transmit antenna/two receiving antennas, 268–273
 - linear diversity multiuser detector, 268–269
 - linear space-time multiuser detector, 269–271
 - performance comparison, 271–273
 - two transmit and two receive antennas, 277–281
 - linear diversity multiuser detector, 278–279
 - linear space-time multiuser detector, 280–281
 - two transmitting antennas/one receive antenna, 273–277
 - linear diversity multiuser detector, 273–275
 - linear space-time multiuser detector, 276–277
 - Additive white Gaussian noise (AWGN), 8, 13, 28, 173, 303, 306, 313, 322, 418, 474, 555
 - Additive white impulsive noise (AWIN) channel, 474
 - Advanced Mobile Phone System (AMPS), 5
 - Akaike information criterion (AIC), 63
 - Applications, wireless communications, 1–2
 - Approximate conditional mean filter; *See* ACM filter
 - Asymptotic multiuser efficiency (AME), 46–48
 - Asymptotic multiuser efficiency under mismatch, 46–49
 - Asymptotic output SINR, 51–59
 - equicorrelated signals with perfect power control, 54–56
 - orthogonal signals, 53–54
 - simulation examples, 56–59
 - Asymptotic performance of robust multiuser detection, 182–187
 - asymptotic probability of error, 183–187
 - linear decorrelating detector, 185
 - maximum-likelihood decorrelating detector, 185–186
 - minimax decorrelating detector, 186–187
 - influence function, 182–183
 - Asymptotic probability of error, 183–187
 - Asynchronous CDMA:
 - sliding window group-blind detector for, 335–339
 - simulation examples, 339
 - Autoregressive interference, 414–416
- ## B
- Basic receiver signal processing, 13–21
 - Batch processing vs. adaptive processing, 449–451
 - Bayes' formula, 15
 - Bayesian MCMC demodulator, 559–569
 - Bayesian blind turbo receiver, 564–565
 - conditional posterior distributions, 560–561
 - Gibbs sampler with local linearization, 562
 - Metropolis-Hastings algorithm, 561–562
 - null sampling, 563
 - prior distributions, 559

- sampling frequency offset, 561–563
- simulation examples, 565–569
 - large frequency offset example, 569
 - performance degradation due to frequency offset, 565
 - performance of various frequency offset sampling methods, 565–566
 - small frequency offset example, 566–569
- Bayesian multiuser detection:
 - in coded systems, 469–477
 - in Gaussian noise, 458–464
 - in impulsive noise, 464–469
 - via MCMC, 455–477
- Bayesian multiuser detection in coded systems, 469–477
 - code-constrained Gibbs multiuser detector, 472–473
 - decoder-assisted convergence assessment, 472
 - Gibbs sampler-EM algorithm relationship, 473–474
 - simulation examples, 474–477
 - turbo multiuser detection in unknown channels, 469–472
- Bayesian multiuser detection in Gaussian noise, 458–464
 - Bayesian interference, 458–459
 - conditional posterior distributions, 460–461
 - Gibbs multiuser detector in Gaussian noise, 461–463
 - prior distributions, 459–460
 - simulation examples, 463–464
- Bayesian multiuser detection in impulsive noise, 464–469
 - conditional posterior distributions, 466–467
 - Gibbs multiuser detector in impulsive noise, 467–468
 - prior distributions, 465–466
 - simulation examples, 468–469
- Bayesian multiuser detection via MCMC, 455–477
 - system description, 455–458
- Bayesian signal processing, 448–451
 - batch processing vs. adaptive processing, 449–451
 - framework, 448–449
 - Monte Carlo methods, 451
- Binary phase-shift keying (BPSK), 15
- Blind adaptive channel estimation, 295–301
 - discrete-time channel model, 295–297
 - problem, 297–299
 - simulation results, 299–301
- Blind adaptive equalization of MIMO channels via SMC, 488–494
 - SMC blind adaptive equalizer for MIMO channels, 490–494
 - system description, 489–490
- Blind channel estimation, 77–82
- Blind channel identification, 86
- Blind MCMC receiver for coded OFDM systems with frequency-selective fading and frequency offset, 555–569
- Bayesian MCMC demodulator, 559–569
 - Bayesian blind turbo receiver, 564–565
 - computer data posterior probabilities, 563–564
 - conditional posterior distributions, 560–561
 - Gibbs sampler with local linearization, 562
 - Metropolis-Hastings algorithm, 561–562
 - null sampling, 563
 - prior distributions, 559
 - sampling frequency offset, 561–563
 - simulation examples, 565–569

- system description, 556–558
 - Bayesian formulation of optimal demodulation, 557–558
 - channel model with frequency offset, 556–557
 - Blind MMSE space-time multiuser detection, 294
 - Blind multiuser detection, 22, 27–107
 - algorithms, 28
 - blind multiuser detector performance, 49–59
 - in correlated noise, 86–92
 - canonical correlation decomposition, 88–90
 - simulation examples, 90–92
 - singular value decomposition, 87–88
 - direct methods, 32–41
 - LMS algorithm, 34–35
 - QR-RLS algorithm, 37–41
 - RLS algorithm, 35–36
 - linear decorrelating detector, 30–31
 - linear MMSE detector, 31–32
 - linear receivers for synchronous CDMA, 28–32
 - linear decorrelating detector, 30–31
 - linear MMSE detector, 31–32
 - synchronous CDMA signal model, 28–30
 - in multipath channels, 71–92
 - adaptive receiver structures, 82–86
 - blind channel estimation, 77–82
 - decimation-combining linear detectors, 75–77
 - linear correlating detector, 74
 - linear MMSE detector, 74–75
 - linear multiuser detectors, 73–77
 - multipath signal model, 71–73
 - subspace linear detectors, 75
 - subspace methods, 41–49
 - asymptotic multiuser efficiency under mismatch, 46–49
 - detector estimate asymptotics, 45–46
 - linear decorrelating detector, 41–43
 - linear MMSE detector, 43–44
 - subspace tracking algorithms, 59–71
 - NAHJ subspace tracking, 68–71
 - PASTd algorithm, 62–66
 - QR-Jacobi methods, 66–68
 - synchronous CDMA signal model, 28–30
 - timing-free, 27
 - Blind multiuser detector performance, 49–59
 - asymptotic output SINR, 51–59
 - equicorrelated signals with perfect power control, 54–56
 - orthogonal signals, 53–54
 - simulation examples, 56–59
 - performance measures, 49–50
 - Blind robust multiuser detector, 199–201
 - Bluetooth, 4, 5, 385, 407
 - radio-on-a-chip, 2
- ## C
- Cameron-Martin formula, 242, 340
 - Canonical correlation decomposition, 88–90
 - Cauchy-Schwartz inequality, 31
 - CDMA with turbo coding:
 - turbo multiuser detection in, 346–356
 - soft turbo encoder, 347–351
 - turbo encoder, 356–357
 - turbo multiuser receiver in turbo-coded CDMA with multi-path fading, 351–356

- Cellular telephony:
 - growth rate, 2
 - subscription rate, 2
- Chip waveform, 3–4
- Cholesky factorization, 37
- Co-channel interference (CCI), 9–11
- Code-aided techniques, 389, 407–419
 - autoregressive interference, 414–416
 - digital interference, 416–419
 - NBI suppression via linear MMSE detector, 408–410
 - tonal interference, 410–414
- Coded OFDM systems:
 - advanced signal processing for, 551–613
 - algorithms, 552
 - blind MCMC receiver for:
 - with frequency-selective fading and frequency offset, 555–569
 - LDPC-based space-time coded OFDM systems, 588–612
 - coding design principles, 599–600
 - LDPC-based STC, 600–601
 - low-density parity-check codes, 596–599
 - MAP-EM demodulator, 602–605
 - MAP-EM demodulator initialization, 605–606
 - simulation examples, 606–611
 - turbo receiver, 601–602
 - OFDM communication system, 552–555
 - pilot-symbol-aided turbo receiver for space-time block-coded OFDM systems, 569–588
 - ML receiver based on the EM algorithm, 575–581
 - simplified system model, 574–575
 - system description, 569–574
- Coded systems:
 - Bayesian multiuser detection in, 469–477
 - code-constrained Gibbs multiuser detector, 472–473
 - decoder-assisted convergence assessment, 472
 - Gibbs sampler-EM algorithm relationship, 473–474
 - simulation examples, 474–477
 - turbo multiuser detection in unknown channels, 469–472
- Code-division multiple access (CDMA), 2, 4, 5–7, 27–28, 225–226, 357, 455, *See also* CDMA with turbo coding
 - multicarrier CDMA, 4
- Coding design principles, LDPC-based space-time coded OFDM systems, 599–600
- Coherence time, 505
- Combined single-user/multiuser linear detection, 254–265
 - simulation examples, 256–265
 - convergence of the iterative inference cancellation method, 260
 - performance comparison of multiuser vs. single-user space-time processing, 256–260
 - performance of combined multiuser/single-user space-time processing, 260
 - performance vs. number of antennas/number of users, 260
 - performance vs. spreading gain/number of antennas, 260–265
- Complex-valued discrete-time synchronous CDMA signal model, 201
- Constrained subspace blind detector, 123

Correlated noise:
 blind multiuser detection in,
 86–92
 canonical correlation decompo-
 sition, 88–90
 simulation examples, 90–92
 singular value decomposition,
 87–88
 linear group-blind detection in,
 155–161
 simulation example, 158
 Correlator, 16

D

Decimation-combining linear detectors,
 75–77
 Decision-feedback differential detection,
 514–516
 simulation examples, 516
 Decision-feedback differential detection
 in fading channels, 514–516
 simulation examples, 516
 Decision-feedback space-time differen-
 tial decoding, 516–523
 space-time differential block
 coding, 517–520
 space-time feedback differential
 decoding in flat-fading
 channels, 520–523
 simulation examples, 523
 Decorrelating detector, 21
 Decorrelator, 21
 Delayed estimation, 494, 534–541
 delayed-sample method, 536–538
 delayed-weight method, 534–536
 simulation examples, 539–541
 Delayed-weight method, 540
 Detector estimate asymptotics, 45–46
 Differential detector receiver scheme,
 539
 Diffusive losses, 8
 Digital interference, 416–419
 Digital signal processing (DSP), 21
 Dirac delta function, 11, 341

Direct matrix inversion (DMI) blind
 detector, 33
 Direct methods:
 blind multiuser detection, 32–41
 LMS algorithm, 34–35
 QR-RLS algorithm, 37–41
 RLS algorithm, 35–36
 Direct-matrix-inversion (DMI) method,
 27, 51, 229–230
 Direct-sequence spread-spectrum
 (DS-SS) format, 287
 Discrete Fourier transform (DFT), 219,
 551

E

Effective sample size, 487
 Entropic narrowband stochastic
 processes, 391
 Equalization, 17–19
 maximum-likelihood sequence
 detector (MLSD), 18
 minimum-mean-square-error
 (MMSE) linear equalizer, 19
 sequence detection, 17
 zero-forcing equalizer (ZFE), 19
 Equicorrelated signals with perfect
 power control:
 form I group-blind detectors,
 127–129
 form II group-blind hybrid detec-
 tor, 121–125
 Exhaustive-search and decorrelative
 detection, 201–204
 Expectation-maximization (EM) algo-
 rithm, 25, 455, 507–508, 555
 Extrinsic information, 305

F

Fading channels:
 algorithms, 503–504
 coherent detection in, 507–514
 decision-feedback differential
 detection in, 514–516
 simulation examples, 516

- decision-feedback space-time differential decoding, 516–523
 - space-time differential block coding, 517–520
 - space-time feedback differential decoding in flat-fading channels, 520–523
 - expectation-maximization (EM) algorithm, 507–508
 - flat-fading channels:
 - adaptive SMC receivers for, 523–548
 - expectation-maximization (EM) receiver in, 508–510
 - space-time feedback differential decoding in, 520–523
 - flat-fading synchronous CDMA channels:
 - linear multiuser detection in, 511–512
 - frequency-flat, single-user receivers in, 501–502
 - frequency-nonselective, 505–506
 - frequency-selective, 506–507
 - single-user receivers in, 502–503
 - multipath fading channels, statistical modeling of, 504–507
 - multiuser receivers in, 503
 - sequential EM (expectation-maximization) algorithm, 512–514
 - signal processing for, 501–540
- Fading Gaussian noise channels, adaptive receiver in:
- coded case, 541–544
 - simulation examples, 544
 - uncoded case, 531–534
- Fading impulsive noise channels:
- adaptive receivers in, 544–548
 - simulation examples, 547–548
- Fast fading, 25, 505
- Fast hopping, 4
- Flat fading, 505
- Flat-fading channels:
- adaptive SMC receivers for, 523–548
 - adaptive receiver in fading Gaussian noise channels, 541–544
 - adaptive receivers in fading impulsive noise channels, 544–548
 - delayed estimation, 534–541
 - system description, 527–530
 - expectation-maximization (EM) receiver in, 508–510
 - space-time feedback differential decoding in, 520–523
- Flat-fading channels, space-time feedback differential decoding in, 520–523
- Flat-fading synchronous CDMA channels, linear multiuser detection in, 511–512
- Forgetting factor, 36, 429
- Form I group-blind detectors, 125–129
 - equicorrelated signals with perfect power control, 127–129
 - orthogonal signals, 127
- Form II group-blind hybrid detector, 119–125
 - equicorrelated signals with perfect power control, 121–125
 - orthogonal signals, 121
- Frame, transmitting, 3
- Frame-error rate (FER), 368, 371
- Frequency hopping (FH), 385
- Frequency nonselective fading, 505
- Frequency-division multiple access (FDMA), 5
- Frequency-division multiplexing (FDM), 551
- Frequency-flat fading channels, single-user receivers in, 501–502
- Frequency-nonselective fading channels, 505–506
- Frequency-selective fading, 8, 11, 505–507

G

Gaussian minimum-shift-keying
 (GMSK) modulation, 455

Gaussian noise, 23

- Bayesian multiuser detection in, 458–464
- Bayesian interference, 458–459
- conditional posterior distributions, 460–461
- Gibbs multiuser detector in
 - Gaussian noise, 461–463
 - prior distributions, 459–460
 - simulation examples, 463–464

Gauss-Seidel iteration, 248

Genie-aided lower bound receiver scheme, 539

Gibbs sampler, 451, 453–454, 458–459, 472, 474

Givens rotations, 68

Global System for Mobile (GSM), 5

Group-blind multiuser detection, 109–171

- adaptive group-blind linear multiuser detection, 151–155
- simulation examples, 153–155

algorithms, 109–110

group-blind multiuser detection in multipath channels, 140–161

linear group-blind detection in correlated noise, 155–161

- simulation example, 158

linear group-blind detectors, 143–151

- simulation examples, 147–151

linear group-blind multiuser detection for synchronous CDMA, 110–119

nonlinear group-blind detection, 158–161

- simulation examples, 161

nonlinear group-blind multiuser detection, 135–140

nonlinear group-blind multiuser detection for synchronous

CDMA, 129–140

- slowest-descent search, 133–135

performance of, 119–129

- form I group-blind detectors, 125–129
- form II group-blind hybrid detector, 119–125

Group-blind multiuser detection in multipath channels, 140–161

Group-blind SISO multiuser detector, 329–335

Growth rate, cellular telephony, 2

Guard interval, 551

H

HiperLAN, 2, 385

HMM-based methods, 407

Huber decorrelator, 220–222

Huber penalty function, 190, 204, 206

I

Ideal interleaving, 600

IEEE 802.11, 2, 385

IEEE 802.16 wireless MAN standards, 5

Impulsive noise:

- Bayesian multiuser detection in, 464–469
- conditional posterior distributions, 466–467
- Gibbs multiuser detector in
 - impulsive noise, 467–468
 - prior distributions, 465–466
 - simulation examples, 468–469

Industrial, scientific and medical (ISM) bands, 385

Infinite-impulse-response (IIR) filter, 394

Influence function (IF), 182–183

Intercarrier interference (ICI), 551

Interference, 9

Interference-to-signal ratio (ISR), 434

Intersymbol interference (ISI), 9, 73, 447, 449, 455, 551

- Inverse discrete Fourier transform (IDFT), 552
- Irregular LDPC code, 597
- IS-95 (Interim Standard 95), 7
- Iterative interference cancellation, linear multiuser detection via, 247–251
- J**
- Jacobi SVD algorithm, 68
- Jakes model, 506
- K**
- K model, 174
- Kalman-Bucy predictors, 393–395, 399–400
- Kalman-type algorithm, 297
- Known channel lower bound receiver scheme, 539
- L**
- LDPC-based space-time coded OFDM systems, 588–612
 - coding design principles, 599–600
 - LDPC-based STC, 600–601
 - low-density parity-check (LDPC) codes, 596–599
 - MAP-EM demodulator, 602–605
 - initialization, 605–606
 - simulation examples, 606–611
 - performance with ideal CSI, 608–610
 - performance with unknown CSI, 610–611
 - STC-OFDM systems:
 - capacity considerations for, 589–596
 - channel capacity, 591–594
 - pairwise error probability, 594–596
 - system model, 589–591
 - turbo receiver, 601–602
- Least mean squares (LMS), 197
- Least-mean-squares (LMS) algorithm, 22, 229, 395, 429
- Least-squares penalty function, 204
- Linear correlating detector, 74
- Linear decorrelating detector, 30–31, 41–43, 178
- Linear diversity multiuser detector, 268–269, 278–279, 281
- Linear FIR predictor, 394–396
- Linear group-blind detection in correlated noise, 155–161
 - simulation example, 158
- Linear group-blind detectors, 143–151
 - simulation examples, 147–151
- Linear group-blind multiuser detection for synchronous CDMA, 110–119
- Linear minimum mean-square error (MMSE) combining, 228–230, 253
- Linear MMSE detector, 31–32, 43–44, 74–75
 - and RLS blind adaptation rule, 435–437
- Linear MMSE multiuser detector, 21
- Linear multiuser user detection via iterative interference calculation, 247–251
- Linear multiuser detectors, 23, 73–77
- Linear predictive techniques 390–396
 - Kalman-Bucy predictors, 393–395, 399–400
 - linear FIR predictor, 394–396
 - signal models, 390–392
- Linear predictor and interpolator, 420–421
- Linear receivers for synchronous CDMA, 28–32
 - blind multiuser detection, 28–32
 - linear decorrelating detector, 30–31
 - linear MMSE detector, 31–32
 - synchronous CDMA signal model, 28–30

- linear decorrelating detector, 30–31
 - linear MMSE detector, 31–32
 - synchronous CDMA signal model, 28–30
 - Linear space-time multiuser detection, 247–265
 - combined single-user/multiuser
 - linear detection, 254–265
 - simulation examples, 256–265
 - linear multiuser detection via iterative interference calculation, 247–251
 - single-user linear space-time detection, 251–254
 - linear minimum mean-square error combiner, 253
 - maximum signal-to-interference ratio combiner, 253–254
 - space-time matched filter, 253
 - Linear space-time multiuser detector, 269–271, 280–281
 - Linearly constrained minimum variance (LCMV) array, 34
 - LMS algorithm, 34–36
 - Local likelihood search:
 - robust multiuser detection based on, 201–206
 - exhaustive-search and decorrelative detection, 201–204
 - local-search detection, 204–206
 - simulation results, 206
 - Local-search detection, 204–206
 - Log-likelihood penalty function, 204
 - Log-normal model, 174
 - Long-spreading codes, 4
 - Low-complexity SISO multiuser detector, 319–328
 - Gaussian approximation of linear MMSE filter output, 322–323
 - recursive procedure for computing soft output, 323–325
 - simulation examples, 325–328
 - soft interference cancellation and instantaneous linear MMSE filtering, 319–322
 - Low-density parity-check (LDPC) codes, 25, 552, 596–599
- ## M
- MAP decoding algorithm for convolutional codes, 366
 - MAP decoding algorithm for STTC, 376
 - MAP demodulator, 306
 - MAP-EM demodulator, 602–605
 - initialization, 605–606
 - Markov chain Monte Carlo (MCMC) methods, 24, 325, 447
 - Markov chain Monte Carlo (MCMC)-based Bayesian methods, 434, 555
 - Markov chain Monte Carlo signal processing, 451–454
 - Gibbs sampler, 453–454
 - Metropolis-Hastings algorithm, 452–453
 - Markov chain theory, 451
 - M -ary phase-shift keying (MPSK), 14–15
 - Matched filter, 13–16, 420
 - defined, 16
 - Maximum *a posteriori* probability (MAP), 14–16, 305
 - Maximum *a posteriori* probability (MAP) decoding algorithm, 306
 - Maximum signal-to-interference ratio combiner, 253–254
 - Maximum-likelihood code-aided method, 431–435
 - Maximum-likelihood (ML) decorrelating detector, 179
 - Maximum-likelihood (ML) detection, 14–17
 - Maximum-likelihood (ML) frequency offset estimates, 555

- Maximum-likelihood (ML) multiuser detection, 174
- Maximum-likelihood (ML) multiuser sequence detector, 245–247
- Maximum-likelihood sequence detector (MLSD), 18
- Mean weight vector, convergence of, 437–440
- M-estimator, 178–179
- Metropolis-Hastings algorithm, 451–453
- Middleton models, 174
- MIMO, *See* Multiple-input/multiple-output (MIMO) systems
- Minimax decorrelating detector, 179–181
- Minimum description length (MDL), 63
- Minimum mean-square-error (MMSE) detector, 27, 30–32, 363
- Minimum-mean-square-error (MMSE) linear equalizer, 19
- Minimum-output-energy (MOE) detection, 34
- Mixture Kalman filter (MKF), 487–488
- Monte Carlo Bayesian signal processing, 447–500
 - Bayesian multiuser detection:
 - in coded systems, 469–477
 - in Gaussian noise, 458–464
 - in impulsive noise, 464–469
 - via MCMC, 455–477
 - Bayesian signal processing, 448–451
 - batch processing vs. adaptive processing, 449–451
 - framework, 448–449
 - Monte Carlo methods, 451
 - blind adaptive equalization of MIMO channels via SMC, 488–494
 - SMC blind adaptive equalizer for MIMO channels, 490–494
 - system description, 489–490
- Markov chain Monte Carlo signal processing, 451–454
 - Gibbs sampler, 453–454
 - Metropolis-Hastings algorithm, 452–453
- sequential Monte Carlo signal processing, 477–488
 - for dynamical systems, 482–485
 - mixture Kalman filter (MKF), 487–488
 - resampling procedures, 485–487
 - sequential importance sampling, 477–481
- Monte Carlo methods, 451
- Moore’s Law, 1
- M-regression:
 - robust multiuser detection via, 177–181
 - linear decorrelating detector, 178
 - maximum-likelihood (ML) decorrelating detector, 179
 - minimax decorrelating detector, 179–181
- MSE:
 - convergence of, 443–444
- Multicarrier CDMA, 4
- Multipath, 8–9, 306
- Multipath CDMA:
 - adaptive space-time multiuser detection in, 287–301
 - blind adaptive channel estimation, 295–301
 - discrete-time channel model, 295–297
 - problem, 297–299
 - simulation results, 299–301
 - blind MMSE space-time multiuser detection, 294
 - signal model, 287–294
- Multipath channels:
 - adaptive receiver structures in, 82–86
 - simulation example, 85–86

- blind multiuser detection in,
 - 71–92
 - adaptive receiver structures, 82–86
 - blind channel estimation, 77–82
 - decimation-combining linear detectors, 75–77
 - linear correlating detector, 74
 - linear MMSE detector, 74–75
 - linear multiuser detectors, 73–77
 - multipath signal model, 71–73
 - subspace linear detectors, 75
 - group-blind multiuser detection in, 140–161
 - Multipath fading:
 - turbo multiuser receiver in turbo-coded CDMA with, 351–356
 - simulation examples, 352–356
 - effect of the S-interleaver, 353–354
 - fast vehicle speed and load data rate, 354
 - medium vehicle speed and medium data rate, 354
 - very slow fading, 354
 - single-user RAKE receiver, 352
 - Multipath fading channels:
 - statistical modeling of, 504–507
 - Multipath signal model, 71–73
 - Multiple-access interference (MAI), 9, 23, 30–32, 173, 408
 - Multiple-access techniques, 5–7
 - code-division multiple access (CDMA), 2, 4, 5–7, 27–28, 225–226, 357, 455
 - frequency-division multiple access (FDMA), 5
 - time-division multiple access (TDMA), 2, 5, 225–226, 357
 - Multiple-input/multiple-output (MIMO) systems, 13, 22–23
 - blind channel identification, 86
 - Multiuser detection, 19–21
 - linear MMSE multiuser detector, 21
 - Multiuser receivers in fading channels, 503
 - Multiuser STBC system, 357–361
 - Multiuser STTC system, 370–373
- ## N
- NAHJ subspace tracking, 68–71, 280
 - algorithm, 69–70
 - simulation example, 70–71
 - Narrowband array assumption, 12
 - Narrowband digital communication signals, 391
 - Narrowband interference (NBI)
 - suppression, 174, 385–446
 - adaptive linear MMSE NBI suppression, 429–431
 - simulation examples, 430–431
 - code-aided techniques, 407–419
 - autoregressive interference, 414–416
 - digital interference, 416–419
 - NBI suppression via linear MMSE detector, 408–410
 - tonal interference, 410–414
 - linear predictive methods, 392–396
 - Kalman-Bucy predictors, 393–395, 399–400
 - linear FIR predictor, 394–396
 - linear predictive techniques, 390–396
 - signal models, 390–392
 - maximum-likelihood code-aided method, 431–435
 - near-far resistance to NBI and MAI by linear MMSE detector, 424–429
 - simulation examples, 427–429
 - nonlinear predictive techniques, 396–406
 - ACM filter, 397–400

- adaptive nonlinear predictor, 400–403
 - HMM-based methods, 407
 - nonlinear interpolating filters, 403–406
 - performance comparisons of techniques, 419–424
 - linear predictor and interpolator, 420–421
 - matched filter, 420
 - nonlinear predictor and interpolator, 421–423
 - numerical examples, 423–424
 - NBI suppression via linear MMSE detector, 408–410
 - Near-far resistance, 46
 - to NBI and MAI by linear MMSE detector, 424–429
 - simulation examples, 427–429
 - Noise density, tail behavior of, 177
 - Noise subspace, 41, 75
 - Nonlinear group-blind detection, 158–161
 - simulation examples, 161
 - Nonlinear group-blind multiuser detection, 135–140
 - for multiuser detection for synchronous CDMA, 129–140
 - simulation examples, 140
 - Nonlinear group-blind multiuser detection for synchronous CDMA, 129–140
 - slowest-descent search, 133–135
 - simulation examples, 135
 - Nonlinear interpolating filters, 403–406
 - Nonlinear predictive techniques, 396–406
 - ACM filter, 397–400
 - adaptive nonlinear predictor, 400–403
 - HMM-based methods, 407
 - nonlinear interpolating filters, 403–406
 - ACM interpolator, 403–404
 - adaptive nonlinear block interpolator, 404–406
 - HMM-based methods, 407
 - simulation examples, 404, 406–407
 - Nonlinear predictor and interpolator, 421–423
 - Nordic Mobile Telephone (NMT), 5
- O**
- OFDM, *See* Orthogonal frequency-division multiplexing (OFDM)
 - One transmit antenna/two receiving antennas, 268–273
 - linear diversity multiuser detector, 268–269
 - linear space-time multiuser detector, 269–271
 - performance comparison, 271–273
 - Optimal space-time multiuser detection, 239–247
 - maximum-likelihood multiuser sequence detector, 245–247
 - signal model, 241–242
 - sufficient statistic, 242–245
 - Orthogonal channels, 5
 - Orthogonal frequency-division multiplexing (OFDM), 2, 22, 25, 551
 - Orthogonal signals:
 - form I group-blind detectors, 127
 - form II group-blind hybrid detector, 121
 - Ostrowski-Reich theorem, 248
- P**
- Parallel interference cancellation method, 250–251
 - PASTd algorithm, 62–66
 - simulation examples, 63–66
 - performance comparison between subspace and MOE blind detectors, 63–66

- tracking performance in a dynamic environment, 66
 - Performance of combined multi-user/single-user space-time processing, 260
 - Performance vs. number of antennas/number of users, 260
 - Performance vs. spreading gain/number of antennas, 260–265
 - Phase-shift-keying (PSK) symbols, 508
 - Pilot-symbol-aided turbo receiver, 581–588
 - ML receiver based on the EM algorithm, 575–581
 - EM-based STBC-OFDM receiver, 576–578
 - initialization of the EM algorithm, 578–581
 - least-squares channel estimator, 578–581
 - pilot-symbol-aided turbo receiver, 581–588
 - simulation examples, 583–584
 - STBC-OFDM receiver based on the MAP-EM algorithm, 582–583
 - simulation examples, 583–584
 - performance of the EM-based ML receiver, 584
 - performance of the MAP-EM-based turbo receiver, 584–588
 - STBC-OFDM receiver based on the MAP-EM algorithm, 582–583
 - Prediction residual, 392
 - Projection-based soft multiuser demodulator, 376
 - Projection-based turbo multiuser detection, 367–370
 - simulation examples, 367–370
 - Propagation losses, 8
- Q**
- QR-Jacobi methods, 66–68
 - QR-RLS algorithm, 37–41
 - Quadrature amplitude modulation (QAM), 14–15
- R**
- RAKE, 2
 - RAKE filter, 13–16
 - RAKE receiver, 13–16, 243, 354–356
 - Rayleigh fading, 8, 11
 - Rayleigh fading channel, 504–505
 - Receiver signal processing for wireless, 13–21
 - equalization, 17–19
 - matched filter/RAKE receiver, 13–16
 - multiuser detection, 19–21
 - Recursive least-squares (RLS) algorithm, 22, 197, 429
 - Rician fading channel, 505
 - RLS algorithm, 35–36
 - RLS linear MMSE detector, 435–446
 - linear MMSE detector, and RLS blind adaptation rule, 435–437
 - mean weight vector, convergence of, 437–440
 - MSE, convergence of, 443–444
 - steady-state SINR, 444
 - training-based RLS algorithm:
 - comparison with, 445–446
 - weight error correlation matrix, 440–443
 - Robust multiuser detection:
 - algorithms, 175
 - asymptotic performance of, 182–187
 - asymptotic probability of error, 183–187
 - linear decorrelating detector, 185
 - maximum-likelihood decorrelating detector, 185–186
 - minimax decorrelating detector, 186–187
 - influence function, 182–183

- based on local likelihood search, 201–206
 - exhaustive-search and decorrelative detection, 201–204
 - local-search detection, 204–206
 - simulation results, 206
 - blind robust multiuser detector, 199–201
 - defined, 197–201
 - extension in multipath channels, 212–215
 - robust blind multiuser detection, 212–213
 - robust group-blind multiuser detection, 212–213
 - least mean squares (LMS), 197
 - least-squares regression/linear decorrelator, 176–177
 - in non-Gaussian channels, 173–224
 - recursive least squares (RLS), 197
 - robust group-blind multiuser detection, 206–211
 - robust multiuser detector implementation, 187–197
 - simulation examples, 192–197
 - in stable noise, 215–222
 - performance, 219–222
 - symmetric stable distribution, 216–219
 - system model, 175–176
 - via M-regression, 177–181
 - linear decorrelating detector, 178
 - maximum-likelihood (ML) decorrelating detector, 179
 - minimax decorrelating detector, 179–181
 - Robust multiuser detector implementation, 187–197
 - simulation examples, 192–197
- S**
- Sequence detection, 17
 - Sequential EM (expectation-maximization) algorithm, 512–514
 - Sequential Monte Carlo (SMC), 24, 447
 - blind adaptive equalization of MIMO channels via, 488–494
 - SMC blind adaptive equalizer for MIMO channels, 490–494
 - system description, 489–490
 - Sequential Monte Carlo (SMC) signal processing, 477–488
 - for dynamical systems, 482–485
 - mixture Kalman filter (MKF), 487–488
 - resampling procedures, 485–487
 - sequential importance sampling, 477–481
 - Shadow fading, 8, 306
 - Signal subspace, 41
 - Signal-to-interference-plus-noise ratio (SINR), 49–52, 174, 396, 409–413, 419
 - asymptotic output SINR, 51–59
 - equicorrelated signals with perfect power control, 54–56
 - orthogonal signals, 53–54
 - simulation examples, 56–59
 - steady-state SINR, 444
 - Single-user linear space-time detection, 251–254
 - linear minimum mean-square error combiner, 253
 - maximum signal-to-interference ratio combiner, 253–254
 - space-time matched filter, 253
 - Single-user modulation techniques, 3–5
 - Single-user/multiuser linear detection, 254–265
 - simulation examples, 256–265
 - convergence of the iterative interference cancellation method, 260
 - performance comparison of multiuser vs. single-user space-time processing, 256–260

- performance of combined multi-user/single-user space-time processing, 260
- performance vs. number of antennas/number of users, 260
- performance vs. spreading gain/number of antennas, 260–265
- Singular value decomposition, 87–88
- SINR, *See* Signal-to-interference-plus-noise ratio (SINR)
- SISO multiuser detector in multipath fading channels, 342–345
 - recursive algorithm for computing soft output, 345–346
- Sliding window group-blind detector for asynchronous CDMA, 335–339
- Slow fading, 505
- Slow frequency hopping, 4
- Slow mixing, 454
- Slowest-descent search, 133–135
 - simulation examples, 135
- Soft demodulator, 601
- Soft LDPC decoder, 601, 605
- Soft multiuser demodulator, 363–364, 373–375
- Soft-input/soft-output (SISO) group-blind multiuser detector, 329–330
- Space-division multiple-access (SDMA), 306, 357, 488
- Space-time block coding (STBC), 356–357
- Space-time block-coded systems:
 - turbo multiuser detection in, 356–370
 - multiuser STBC system, 357–361
 - projection-based turbo multiuser detection, 367–370
 - turbo multiuser receiver for, 361–366
 - MAP decoding algorithm for convolutional code, 366
 - a posteriori* code-bit LLRs, computing, 364–366
 - soft multiuser demodulator, 363–364
- Space-time differential block coding, 265, 517–520
- Space-time feedback differential decoding in flat-fading channels, 520–523
 - simulation examples, 523
- Space-time matched filter, 243, 253
- Space-time multiuser detection (STMUD), 225–301
 - adaptive array processing in TDMA systems, 226–239
 - extension to dispersive channels, 237–239
 - linear MMSE combining, 228–230
 - signal model, 226–228
 - subspace-based training algorithm, 230–237
 - adaptive space-time multiuser detection in multipath CDMA, 287–301
 - blind adaptive channel estimation, 295–301
 - blind MMSE space-time multiuser detection, 294
 - signal model, 287–294
 - adaptive space-time multiuser detection in synchronous CDMA, 265–287
 - blind adaptive implementations, 281–287
 - one transmit antenna/two receiving antennas, 268–273
 - two transmit and two receive antennas, 277–281
 - two transmitting antennas/one receive antenna, 273–277
- algorithms, 226

- linear space-time multiuser detection, 247–265
 - combined single-user/multiuser linear detection, 254–265
 - linear multiuser detection via iterative interference calculation, 247–251
 - single-user linear space-time detection, 251–254
- optimal space-time multiuser detection, 239–247
 - maximum-likelihood multiuser sequence detector, 245–247
 - signal model, 241–242
 - sufficient statistic, 242–245
- Space-time trellis coding (STTC), 356–357, 600
- Space-time trellis-coded systems:
 - turbo multiuser receiver for, 373–379
 - MAP decoding algorithm for STTC, 376
 - a posteriori* code symbol LPs, computing, 375–376
 - multiuser STTC system, 370–373
 - projection-based soft multiuser demodulator, 376
 - simulation examples, 377
 - soft multiuser demodulator, 373–375
- Spread-spectrum systems, 24
 - ability to coexist with narrow-band systems, 386
- S-random interleaver, 353–354
- Stable noise:
 - robust multiuser detection in, 215–222
 - performance, 219–222
 - symmetric stable distribution, 216–219
- STC-OFDM systems:
 - capacity considerations for, 589–596
 - channel capacity, 591–594
 - pairwise error probability, 594–596
 - system model, 589–591
- Steady-state SINR, 444
- Subspace linear detectors, 75
- Subspace methods, 41–49
 - asymptotic multiuser efficiency under mismatch, 46–49
 - blind multiuser detection, 41–49
 - asymptotic multiuser efficiency under mismatch, 46–49
 - detector estimate asymptotics, 45–46
 - linear decorrelating detector, 41–43
 - linear MMSE detector, 43–44
 - detector estimate asymptotics, 45–46
 - linear decorrelating detector, 41–43
 - linear MMSE detector, 43–44
- Subspace tracking, 22
- Subspace tracking algorithms, 59–71
 - NAHJ subspace tracking, 68–71
 - PASTd algorithm, 62–66
 - QR-Jacobi methods, 66–68
- Subspace-based training algorithm, 230–237
 - steering vector estimation, 230–235
 - weight vector calculation, 236–237
- SVD-based subspace tracking algorithms, 66–68
- Symmetric stable distribution, 216–219
- Synchronous CDMA:
 - adaptive space-time multiuser detection in, 265–287
 - blind adaptive implementations, 281–287
 - adaptive blind linear space-time multiuser detection, 285–287

- batch blind linear space-time multiuser detection, 284–285
 - one transmit antenna/two receiving antennas, 268–273
 - linear diversity multiuser detector, 268–269
 - linear space-time multiuser detector, 269–271
 - performance comparison, 271–273
 - two transmit and two receive antennas, 277–281
 - linear diversity multiuser detector, 278–279
 - linear space-time multiuser detector, 280–281
 - two transmitting antennas/one receive antenna, 273–277
 - linear diversity multiuser detector, 273–275
 - linear space-time multiuser detector, 276–277
 - linear receivers for, 28–32
 - blind multiuser detection, 28–32
 - linear decorrelating detector, 30–31
 - linear MMSE detector, 31–32
 - synchronous CDMA signal model, 28–30
 - linear decorrelating detector, 30–31
 - linear MMSE detector, 31–32
 - synchronous CDMA signal model, 28–30
 - turbo multiuser detection for, 313–328
 - low-complexity SISO multiuser detector, 319–328
 - optimal SISO multiuser detector, 317–319
 - turbo multiuser receiver, 313–317
 - Synchronous CDMA signal model, 28–30
- ## T
- Tapped-delay-line (TDL) configuration, 394
 - Third-generation (3G) cellular, 2
 - Time-division multiple access (TDMA), 2, 5, 225–226, 357
 - Time-division multiple access (TDMA) systems:
 - adaptive array processing in, 226–239
 - extension to dispersive channels, 237–239
 - linear MMSE combining, 228–230
 - signal model, 226–228
 - subspace-based training algorithm, 230–237
 - Time-nonselective fading, 505
 - Time-selective fading, 8–9, 505
 - Timing-free blind multiuser detection, 27
 - Tonal interference, 410–414
 - Tonal signals, 391
 - Tone jammers, 391
 - Training-based RLS algorithm,
 - comparison with, 445–446
 - Transform domain NBI suppression, 388
 - Turbo encoder, 356–357
 - Turbo equalizer, 306
 - Turbo multiuser detection, 303–384
 - algorithms, 306–308
 - in CDMA with turbo coding, 346–356
 - soft turbo encoder, 347–351
 - turbo encoder, 356–357
 - turbo multiuser receiver in turbo-coded CDMA with multipath fading, 351–356

- MAP decoding algorithm for
 - convolutional codes, 308–313
- with multipath fading, 339–346
 - signal model, 339–342
- SISO multiuser detector
 - in multipath fading channels, 342–345
- in space-time block-coded systems, 356–370
 - multiuser STBC system, 357–361
 - projection-based turbo multiuser detection, 367–370
 - turbo multiuser receiver for STBC system, 361–366
- in space-time trellis-coded systems, 370–379
 - multiuser STTC system, 370–373
 - turbo multiuser receiver for STTC system, 373–379
- for synchronous CDMA, 313–328
 - low-complexity SISO multiuser detector, 319–328
 - optimal SISO multiuser detector, 317–319
 - turbo multiuser receiver, 313–317
- turbo processing, 303–308
- with unknown interferers, 328–339
 - group-blind SISO multiuser detector, 329–335
 - signal model, 328–329
 - sliding window group-blind detector for asynchronous CDMA, 335–339
- Turbo multiuser receiver for STBC system, 361–366
 - MAP decoding algorithm for convolutional code, 366
 - a posteriori* code-bit LLRs, computing, 364–366
 - soft multiuser demodulator, 363–364
- Turbo multiuser receiver for STTC system, 373–379
 - MAP decoding algorithm for STTC, 376
 - a posteriori* code symbol LPs, computing, 375–376
 - projection-based soft multiuser demodulator, 376
 - simulation examples, 377
 - soft multiuser demodulator, 373–375
- Turbo multiuser receiver in turbo-coded CDMA with multi-path fading, 351–356
 - simulation examples, 352–356
 - effect of the S-interleaver, 353–354
 - fast vehicle speed and load data rate, 354
 - medium vehicle speed and medium data rate, 354
 - very slow fading, 354
 - single-user RAKE receiver, 352
- Turbo receiver:
 - LDPC-based space-time coded OFDM systems, 601–602
- Two transmit and two receive antennas, 277–281
 - linear diversity multiuser detector, 278–279
 - linear space-time multiuser detector, 280–281
- Two transmitting antennas/one receive antenna, 273–277
 - linear diversity multiuser detector, 273–275
 - linear space-time multiuser detector, 276–277
- Two-stage adaptive detector, 35
- Two-term Gaussian mixture distribution, 174

U

- Ultra-wideband (UWB) modulation, 4–5
- Uncorrelated scattering, 505
- Uniform linear array (ULA), 12

V

- Very high frequency (VHF) systems, 385

W

- Weibull model, 174
- Weight error correlation matrix, 440–443
- Wideband CDMA (WCDMA) standards, 265, 385
- WiFi systems, 2
- WiMax systems, 2
- Wireless channel, 7–13
 - additive white Gaussian noise (AWGN), 8, 13, 28, 173, 303, 306, 313, 322, 418, 474
 - co-channel interference (CCI), 9–11
 - corruption by ambient noise, 7–8
 - diffusive losses, 8
 - frequency-selective fading, 8, 11
 - interference, 9
 - intersymbol interference (ISI), 9, 447, 455

- multipath, 8–9
- multiple-access interference (MAI), 9
- multiple-input/multiple-output (MIMO) systems, 13
- narrowband array assumption, 12
- propagation losses, 8
- Rayleigh fading, 8, 11
- shadow fading, 8
- time-selective fading, 8–9
- uniform linear array (ULA), 12

Wireless communications:

- adaptive array techniques for, 225
- applications, 1–2
- basic receiver signal processing, 13–21
- growth of, 1
- Wireless local area networks (LANs), 2, 385, 407
- Wireless local loop (WLL) systems, 2
- Wireless metropolitan area network (MAN) systems, 2
- Wireless signaling environment, 3–13
 - multiple-access techniques, 5–7
 - single-user modulation techniques, 3–5
 - wireless channel, 7–13
- Wireless system, signal model in, 10

Z

- Zero-forcing equalizer (ZFE), 19