Subject Index

A
AIC criterion, 439, 479, 680, 681
measurement example, 480–481
simulation examples, 439–441
Akaike's information theoretic criterion
See AIC criterion
alias error
See discrete Fourier transform
almost surely
See limits—(with probability 1
aluminum plate
See measurement examples
anti-alias filter
See band-limited assumption
approximate maximum likelihood
See maximum likelihood
ARMA
continuous-time, 201
definition, 200
identification, 401–410
ARMAX
continuous-time, 201
definition, 200
identification, 401–410
ARX
continuous-time, 201
definition, 200
identification, 401–410
asymptotic bias
frequency domain estimators, 297, 299, 387,
407, 472
how to calculate?, 594
semilinear models, 673
simple example, 600
SML estimator, 387, 472
asymptotic covariance
See covariance matrix
asymptotic efficiency
consistent estimators, 590
definition, 587
frequency domain estimators, 297, 299, 318,
408
how to prove?, 595
maximum likelihood, 25, 300, 408
semilinear models, 674, 691
simple example, 599–600
See also Cramér-Rao lower bound and Fisher
information matrix
asymptotic normality
definition, 587
frequency domain estimators, 295, 298, 387,
391, 393, 407, 472
how to prove?, 595
maximum likelihood, 25, 318, 407
semilinear models, 673–674
simple example, 598
SML estimator, 387, 472
asymptotic properties
frequency domain estimators, 298–301, 329,
339–341, 387–396, 399–401, 472–474
general introduction, 12–16, 586–588
how to prove?, 591–595
maximum likelihood, 25, 317–318, 406–410
pitfalls, 595–596
semilinear models, 670–675
simple example, 596–601
SML estimator, 387–390, 472–474
weighted nonlinear least squares with deterministic weighting, 637–638
weighted nonlinear least squares with stochastic weighting, 659–660
asymptotically unbiased, 587–588
definition, 587
versus consistency, 595–596
autocorrelation, 568
auto-power spectrum, 568

B
band-limited assumption, 44, 499
measurement example, 504–508
band-limited white noise
definition, 197
Bayes estimator, 25–27
definition, 25
simple examples, 26–27
Berry and Esseen theorem, 585
best linear approximation, 78–92
asymptotic variance, 87
closed loop, 93–94, 133, 138–139, 242, 254
definition, 79
direct measuring method, 83
discrete-time systems, 88–89
identification, 346, 396–398, 479–480
indirect measuring method, 93, 133–134, 254–260
properties, 83–86
See also Riemann equivalence class
bias
definition, 568
on FRF, See frequency response function measurement
on FRM, See frequency response matrix measurement
test, 572–573
See also asymptotic bias and asymptotically unbiased
BJ
See Box-Jenkins
BLA
See best linear approximation
black box models, 17
BL-assumption
See band-limited assumption
bootstrapped total least squares, 320–321
definition, 320
properties, 320–321, 339–341
Borel-Cantelli lemma, 580
bounded real
See transfer function models
Box-Jenkins
continuous-time, 201
definition, 201
hybrid, 201
identification, 401–410
BTLS See bootstrapped total least squares

C
C-ARMAX
See ARMAX, continuous-time
C-ARMA
See ARMA, continuous-time
C-ARX
See ARX, continuous-time
Cauchy-Schwarz inequality, 614
C-BI
See Box-Jenkins, continuous-time
central limit theorems, 585–586
correlation rate, 585
elementary, 586
Chebyshev’s inequality, 570
chirp
See periodic signals—sweep sine
circular complex
definition, 569
normally distributed, 569
closed loop identification
See feedback
C-OE
See output error model, continuous-time
coherence, 53–54
combining experiments, 541–542
compact parameter space, 293, 628
concatenated data sets
identifiability, 193
identification, 289–330, 472
models, 189–190
See also frequency response matrix measurement
condition number, 549
conditional maximum likelihood
See maximum likelihood
consistency, 13–14
definitions, 587
frequency domain estimators, 297, 299, 329, 387, 391, 393, 396, 407, 472
how to prove?, 591
maximum likelihood, 25, 318, 407
simple example, 597
SML estimator, 387, 472
versus asymptotic unbiasedness, 595–596
continuous-time systems
identification, 301–330, 386–396
measurement examples, 334–339, 398–399
models, 182–194
noise models, 197–199
convergence
See limits
convergence in mean square
See limits—in mean square
convergence rate
central limit theorem, 585
how to prove?, 592
law of large numbers, 583
simple example, 598
correlation residuals
See sample correlation residuals
cost function, 19, 279, 289
ersors-in-variables, 281
interpretation of estimators, 11–12
covariance, 567
covariance matrix
calculation of, 571
definition, 568
frequency domain estimators, 298, 299, 388, 389, 391, 394, 408, 473
FRM, See frequency response matrix measurement
linear least squares, 21
lower bound, see also Cramer-Rao lower bound
maximum likelihood, 318–319, 408
nonlinear least squares, 21
semilinear models, 673–674
SML estimator, 389, 475–476
weighted nonlinear least squares, 23
Cramer-Rao lower bound, 14–16, 588–590
biased estimators, 590
frequency domain estimators, 318, 408, 409
generalized bound, 589, 614
overparameterized models, 702–703
semilinear models, 668–670, 685
unbiased estimators, 589
crest factor, 153
cross-correlation, 568
cross-covariance matrix, 568
cross-power spectrum, 568
cumulant
definition, 569
Gaussian random variables, 570
properties, 570

D
data acquisition
See experimental setup and intersample behavior
delay
identification, 344
model, 184
derivatives
fractional, 208
w.r.t. a matrix, 555
w.r.t. a vector, 554
detrending, 520
DFT
See discrete Fourier transform
difference equation, 182
differential equation, 181
fractional, 208
diffusion phenomena
identification, 301–330, 386–396
model, 179
discrete Fourier transform, 34–43
alias error, 35
basic theory, 35–40
leakage error, 36–37, 40–42
of burst signals, 42–43
of noise, 601–605
of periodic signals, 40–42
windowing, 36–37, 40–42
discrete interval binary sequence
See periodic signals
discrete-time systems
identification, 301–330, 386–396
models, 182–194
noise models, 196–197
dispersion function, 169
distribution
See asymptotic normality
D-optimal
See optimal experiments
drift, 536

E
efficiency, 14–16
definition, 16
See also asymptotic efficiency
eigenvalues, 546
eigenvectors, 546
equation error, 289
errors-in-variables, 280–281, 527
estimator
properties, See asymptotic properties
See frequency domain identification—estimators and
Markov estimator
exact maximum likelihood
See maximum likelihood
excitation signals
general purpose, 155–162
nonparametric measurements, 152–167
optimized, 162–167, 167–172
parametric measurements, 167–172
periodic versus random, 520–522
quality indicators, 153–154
quasi-stationary, 294
single sine versus broadband, 154–155
See also periodic signals, random signals and pulse signals
expected value, 567
experiment design
See optimal experiments
experimental setup
band-limited, 44, 198, 501
zero-order-hold, 196, 500
exponentials (complex, damped), 190

F
factorization in poles and zeros
See transfer function models
fast nonparametric method
comparison standard procedure – LPM, 259
local polynomial method (LPM), 253, 258–260
measurement examples, 142–144, 261–262
standard procedure, 135–139
use in parametric modeling, 468–482
feedback, 202, 240, 242, 254
best linear approximation, 93–94, 202
identification, 345–346, 403–410, 411–413, 474
indirect method, 61–62, 133, 138–139
measurement example, 141–145
Fisher information matrix
definition, 589
frequency domain estimators, 318, 408
overparameterized models, 699–703
semilinear models, 669–670
simple example, 15–16
flight flutter analysis
See measurement examples
Fréchet–Shohat lemma, 580
frequency domain experiment, 287
frequency domain identification
assumptions, 293–298, 385–386
asymptotic properties, 298–301, 391, 393, 396,
406–410, 472–474
combining experiments, 243–248, 541–542
data, 286–288
estimators, 301–330, 386–396, 401–410, 470–
474, 476
guidelines, 531–543
intuitive introduction, 279–284
model selection, 437–441, 449–452, 479
model validation, 432–449, 477–479
multivariate systems, 348–349, 410, 470–482
numerical algorithms, 289–291, 474–475
overview properties, 339–341, 399–401
plant models, 288–289
quick analysis tools, 291–292
versus time domain identification, 522–527
frequency response function measurement
bias, 46, 55–56
certainty region, 48–49, 51
guidelines, 68–69
in the presence of nonlinear distortions, 78–92
indirect method, 61–62
instrumental variables, 62
leakage, 59–60
multivariable systems, See frequency response
matrix measurement
uncertainty bound, See confidence region
using overlapping segments, 62–64
using periodic excitations, 44–54
using random excitations, 54–60
variance, 46–47, 56–58
windowing, 60
frequency response matrix measurement
bias, 231, 236, 260
concatenated data sets, 243–248
confidence regions, 236–237
covariance, 66, 232, 236, 241
ill-conditioned, 67
in the presence of nonlinear distortions, 92–93,
241–243, 254–260
indirect method, 240–241
local polynomial method, 228–233
spectral analysis method, 233–236
using periodic excitations, 64–67, 92–93, 248–
263
using random excitations, 227–248
FRF measurement
See frequency response function measurement
FRM measurement
See frequency response matrix measurement
Frobenius norm, 547
F-test, 51, 477, 573

G
generalized right singular vectors, 549
generalized singular value decomposition, 549
generalized singular values, 549
generalized total least squares, 313–314
definition, 313
properties, 313, 339–341
Gram-Schmidt orthogonalization
definition, 558
examples, 558–560
GSVD
See generalized singular value decomposition
GTLS
See generalized total least squares
guidelines
advanced FRM measurements, 268–269
FRF measurements, 68–69
identification, 531–543
model selection, 452
Subject Index

**H**
- half-sine window, 63
- Hammerstein system, 85–86
- Hanning window, 40
- Hermitian part, 547
- Hessian, 295
- high-order systems
  - identification, 341–344
  - models, 183, 186
  - See also orthogonal polynomials
- Hotelling's 7-test, 237, 477, 572
- hybrid Box-Jenkins model
  - definition, 201
  - identification, 410
  - measurement example, 410–411

**I**
- idempotent matrix, 551
- identifiability, 191–193
  - definition, 191
  - global, 191
  - local, 191
- identification
  - basic choices, 497–529
  - basic steps, 17–19
  - guidelines, 531–543
  - imposing constraints, 528–529
  - introduction, 1–28
  - simple example, 2–12, 27, 576–578, 596–601
  - time versus frequency domain, 522–527
- ill-conditioned, 549
- Illustration, 126
- indecomposable partitions
  - See indecomposable sets
- indecomposable sets, 606–607
- infinity-norm, 548
- initial conditions
  - See equivalent initial conditions
- initial parameters
  - See starting values
- inner product
  - definition, 556
  - examples, 556–558
- instrumental variables, 27–28, 323–324
  - definition, 28, 323
  - frequency response function measurement, 62
  - properties, 323–324, 339–341
  - simple example, 27
- intersample behavior, 498–512
  - band-limited assumption, 499
  - impact on the identification methods, 512
  - impact on the measurement setup, 511–512
  - impact on the model, 500–504, 509–511
  - measurement example, 504–508
  - violation of the assumption, 502–504, 530
- zero-order-hold assumption, 498
- IQML
  - See iterative quadratic maximum likelihood
- iterative quadratic maximum likelihood, 319–320
  - definition, 319
  - properties, 320, 339–341
- IV
  - See instrumental variables
- IWLS
  - See weighted linear least squares

**J**
- Jacobian
  - (frequency) scaling, 290–291, 475
  - definition, 290
  - maximum likelihood estimator, 365
  - multivariate systems, 474
  - pseudo-, 474
  - SML estimator, 474
  - joint input-output method, 410

**K**
- Kronecker product, 552

**L**
- law of the iterated logarithm, 583
- laws of large numbers, 583–585
  - convergence rate, 583
  - example, 584
  - law, 583
  - strong law, 583
  - weak law, 583
- leakage error
  - See discrete Fourier transform and frequency response function measurement
- left singular vectors, 546, 548
- Levenberg-Marquardt, 291, 366
- likelihood function, 14
  - limits, 578–583
  - definitions, 578
  - examples, 580–581
  - in distribution, 578
  - in law, 578
  - in mean square, 578
  - in probability (in prob.), 578
  - interrelations, 579–581
  - preliminary example, 576–578
  - properties, 582–583
  - with probability 1 (w.p. 1), 578
- linear least squares, 21–22, 301–305
  - definition, 21, 301
  - properties, 301–303, 339–341
  - simple example, 22
- linear time invariant second order equivalent, 89
- local polynomial method
bias-variance trade-off, 239–240
comparison with spectral analysis method, 237–239
correlation coefficient, 248–249
correlation matrix, 31–32, 318–319
covariance matrix, 318–319
definition, 23, 315
detector, 409
diagonalization, 365–366
detector, 409
diagonalization, 365–366
dynamic system, 235–236
earl, 365–366
identification, 346–348
identification, 346–348
models, 188–189
mixing random variables
(1) law of large numbers, 584, 611
central limit theorem, 586, 613
definition, 573–574
properties, 574–576
model
See models
model errors
classification, 444–448
detection, 442–444
model selection
frequency domain, 437–441, 449–452, 479
guidelines, 452
measurement example, 448–449, 480–482
semilinear models, 680–682
model validation
frequency domain, 432–436, 477–479
measurement example, 448–449, 480–482
semilinear models, 681
models
damped (complex) exponentials, 190–191
equivalent initial conditions, 185
identification, 191–193
linear-in-the-parameters, 18
nonparametric, 17, 33, 195
over-parameterized, 699–708
semilinear, 665–666
transfer function, 177–202
white box versus black box, 17
Moore-Penrose pseudoinverse, 550–551
MSE
See mean square error
multiple-input, multiple-output
See multivariable systems
multisine
crest factor optimized, 162–164
Fisher optimized, 168–170
full random orthogonal, 93
full random phase, 121
Hadamard, 66
input/output optimized, 165–166
RC-circuit, 504–508
robot, 448–449
beam, 246–248, 515
measurement setup
See experimental setup
MIMO
See multivariable systems
minimum phase region, 181
missing data
identifiability, 192
identification, 346–348
models, 188–189
mixing random variables
(1) law of large numbers, 584, 611
central limit theorem, 586, 613
definition, 573–574
properties, 574–576
model
See models
model errors
classification, 444–448
detection, 442–444
model selection
frequency domain, 437–441, 449–452, 479
guidelines, 452
measurement example, 448–449, 480–482
semilinear models, 680–682
model validation
frequency domain, 432–436, 477–479
measurement example, 448–449, 480–482
semilinear models, 681
models
damped (complex) exponentials, 190–191
equivalent initial conditions, 185
identification, 191–193
linear-in-the-parameters, 18
nonparametric, 17, 33, 195
over-parameterized, 699–708
semilinear, 665–666
transfer function, 177–202
white box versus black box, 17
Moore-Penrose pseudoinverse, 550–551
MSE
See mean square error
multiple-input, multiple-output
See multivariable systems
multisine
crest factor optimized, 162–164
Fisher optimized, 168–170
full random orthogonal, 93
full random phase, 121
Hadamard, 66
input/output optimized, 165–166
RC-circuit, 504–508
robot, 448–449
beam, 246–248, 515
measurement setup
See experimental setup
MIMO
See multivariable systems
minimum phase region, 181
missing data
identifiability, 192
identification, 346–348
models, 188–189
mixing random variables
(1) law of large numbers, 584, 611
central limit theorem, 586, 613
definition, 573–574
properties, 574–576
model
See models
model errors
classification, 444–448
detection, 442–444
model selection
frequency domain, 437–441, 449–452, 479
guidelines, 452
measurement example, 448–449, 480–482
semilinear models, 680–682
model validation
frequency domain, 432–436, 477–479
measurement example, 448–449, 480–482
semilinear models, 681
models
damped (complex) exponentials, 190–191
equivalent initial conditions, 185
identification, 191–193
linear-in-the-parameters, 18
nonparametric, 17, 33, 195
over-parameterized, 699–708
semilinear, 665–666
transfer function, 177–202
white box versus black box, 17
Moore-Penrose pseudoinverse, 550–551
MSE
See mean square error
multiple-input, multiple-output
See multivariable systems
multisine
crest factor optimized, 162–164
Fisher optimized, 168–170
full random orthogonal, 93
full random phase, 121
Hadamard, 66
input/output optimized, 165–166
log-tones, 141, 164
nonlinearity detection, 130–140
odd random phase, 121
orthogonal, 67
random orthogonal, 92
random phase, 76
random phase with random harmonic grid, 121
Riemann equivalent, 123
Schrödinger, 156–157, 504
snow, 163
zippered, 64

multivariable systems
FRF measurement, 64–67
identification, 348–349, 410, 470–479
measurement example, 480–482
models, 193–194
rank residue matrix, 194

N
Newton-Gauss algorithm, 290–291
multivariate systems, 474–475
NLS, NLS-FRF, NLS-I0
See nonlinear least squares
noise after a DFT, 601–605
asymptotic normality, 601
central limit theorem, 602, 605
mixing, 602, 604
strong law of large numbers, 602, 604
noise model, 385
continuous-time, 197–199
discrete-time, 196–197
model structures, 200–201
parametric versus nonparametric, 526
See also nonparametric noise model
See also parametric noise model
nonlinear distortions
See nonlinear systems
nonlinear least squares, 20–21, 305–308
definition, 20, 305, 306
simple example, 310
See also weighted nonlinear least squares
nonlinear systems
continuous-time, 74–78
discrete-time, 180–181
intuitive introduction, 74–75
model, 202
parallel Wiener system, 126
Volterra, 75, 180–181
Wiener-Hammerstein, 85–86
See also best linear approximation
nonlinearity detection, 130–140
fast method, 135–139, 258–260
literature overview, 119–120
measurement example, 141–145
robust method, 130–134, 254–258
nonparametric noise model
use in parametric modeling, 383–401, 463–484
See also measurement examples
normal equations
definition, 290
sensitivity of the solution, 562
normalized model parameter
See scaling
null space, 545, 549

O
OE
See output error model
offset, 536
1-norm, 547
operational amplifier
See measurement examples
optimal experiments
D-optimal, 66, 170
for controller design, 173
measurement example, 171–172
nonparametric measurements, 162–167
parametric measurements, 167–172
orthogonal matrix, 546
orthogonal polynomials
calculation of the roots, 560–561
frequency domain estimators, 341–344
scalar, 558, 559
vector, 559
outliers, 537
output error, 288
output error method
identification, 401–410
output error model
continuous-time, 201
definition, 201
overmodeling
frequency domain, 437–441
semilinear models, 680
simulation examples, 439–441
See also model selection

P
parallel Wiener system
See measurement examples
parametric noise model
identification, 401–410
maximum likelihood solution, 403–410, 524
measurement example, 410–411
model, 195–201
partial fraction expansion
See transfer function models
passivity
See transfer function models
periodic noise
See periodic signals
periodic signals
comparison, 161–162
DFT properties, 40–42
discrete interval binary sequence, 164–165
maximum length binary sequence, 158
optimized multisines, 162–164, 165–166, 167–
172
periodic noise, 77, 122
pseudorandom binary sequence, 157–158
random phase multisine, 77, 121–122
reducing FRF measurement errors, 49–53
Schroeder multisine, 156–157
single sine, 156
spectral representation, 43–44
swept sine, 156
ternary sequence, 65, 166
versus random, 520–522
why should they be used?, 516–520
See also multisines
persistence of excitation
frequency domain, 295
weighted nonlinear least squares, 630, 633
perturbation signals
See excitation signals
plexiglass beam
See measurement examples
positive (semi-)definite, 546
positive real
See transfer function models
prediction error
definition, 402
prediction error method
cost function, 402
frequency domain interpretation, 402
maximum likelihood solution, 524
relation with frequency domain ML solution,
405–406
prefiltering, 517–518
preprocessing, 536–539
pseudorandom binary sequence
See periodic signals
pulse signals, 160–161
Q
QR Factorization, 550
quasi-stationary signals, 294
R
random phase multisine
See periodic signals
random signals
random burst, 160
random noise, 159
versus periodic, 520–522
range space, 546, 549
rank, 545, 549
rational form
See transfer function models
RC-circuit
See measurement examples
reciprocity
See transfer function models
rectangular window, 36
residuals
uncertainty bounds, 433–434
white-colored, 452
resistance measurement problem
See simulation examples
Riemann equivalence class, 120–130
definition, 122–124
invariance BLA, 124–126
measurement example, 126–130
right singular vectors, 546, 548
robot arm
See measurement examples
robust nonparametric method
comparison standard procedure – LPM, 256, 263
local polynomial method (LPM), 252–253,
254–258
measurement examples, 144–145, 261–262
standard procedure, 130–134
use in parametric modeling, 396–398, 468–480
robustness
definition, 587
maximum likelihood estimator, 318
minimum mean square estimators, 588
semilinear models, 674
simple example, 600
S
sample bootstrapped total least squares, 392–395
definition, 393
multivariate, 476
properties, 393–395, 399–401
sample correlation residuals
frequency domain, 445–448, 478–479
semilinear models, 676–678
standard deviation (no modeling errors), 448,
479, 677
variance (modeling errors), 459
sample generalized total least squares, 390–392
definition, 390
multivariate, 476
properties, 391–392, 399–401
sample maximum likelihood, 386–390, 470–480
covariance matrix, 389, 475–476
definition, 386, 470–472
mean and variance cost function, 389, 390, 478
multivariate, 470–479
properties, 387–390, 399–401, 472–474
sample subspace algorithms, 395–396
definition, 395
properties, 390, 399–401
sample variables
frequency domain estimators, 50, 384, 397,
464–470
generalized sample covariance, 464–470
generalized sample mean, 464–470
sample covariance matrix, 572
sample mean, 572
sample variance, 572
stochastic properties, 572–573
See also noise model
sampling, 34–35
SBTLS
See sample bootstrapped total least squares
scaling
frequency, 290
Jacobian matrix, 290, 475
model parameter, 290
SGTLS
See sample generalized total least squares
similarity transformation, 546
simulation examples
comparison frequency domain estimators, 330–
332
comparison starting value algorithms, 332–333
detection of overmodeling, 439–441
influence parameter constraint on transfer
function estimates, 706–708
leakage errors on FRF measurement, 59
noise removal in periodic signals, 518
on-line simulation example for frequency domain
estimators, 286, 302, 303, 308, 351
resistance measurement problem, 2–12, 27,
576–578, 596–601
uncertainty poles and zeros, 435–436
uncertainty transfer function residuals, 434
undermodeling, 442
singular value decomposition, 548–549
singular values, 546, 548
SML
See sample maximum likelihood
spectral analysis method
See frequency response matrix measurement
square root of a matrix, 550
SSUB
See sample subspace algorithms
stability
See transfer function models
stability region, 181
starting values, 282–283, 332–333
state space equations, 182
state space representation
See transfer function models
stationarity, 568
steel beam
See measurement examples
step-invariant transformation, 180, 500
stochastic limit
See limits
strong consistency
See consistancy
strong convergence
See limit with probability 1
SUB
See subspace algorithms
subspace algorithms, 324–330
definition, 325–329
properties, 329–330, 339–341
SVD
See singular value decomposition
systems
continuous-time, 74–78, 177–179
discrete-time, 179–181
distributed continuous-time, 178
lumped continuous-time, 177
nonlinear, 74–78, 180–181
T
ternary sequence
See periodic signals
time delay
See delay
time domain experiment, 286
time domain identification
versus frequency domain identification, 522–
527
time factor, 154
total least squares, 310–312
definition, 312
introduction, 310–312
properties, 312, 339–341
trace, 547
transfer function models, 182–190, 195–201
bounded real, 528
factorization in poles and zeros, 183
identifiability, 191–193
imposing constraints, 528–529
minimum phase region, 181
multivariable systems, 193–194
noise models, 195–201
orthogonal polynomials, 183, 186
partial fraction expansion, 182, 186
passivity (positive real), 528
plant models, 182–184
rational form, 182, 186
reciprocity, 528
relation with DFT spectra, 184–190
stability, 528
stability region, 181
state space representation, 184, 186
time delay, 184
trends, 520, 536
truncated estimator, 297, 635
2-norm, 548

U
unbiased, 13–14
definition, 587
See also asymptotically unbiased
undermodeling
frequency domain, 441–449
measurement example, 448–449
semilinear models, 681
simulation example, 442
uniform convergence, 628
unitary matrix, 546

V
validation, 542–543
See also model validation
variance, 567
on FRF measurements, 46–47, 56–58
See also sample variables—sample variance
Volterra systems
continuous-time, 75
discrete-time, 180–181

W
weak consistency
See consistency
weak convergence
See limit in probability
weighted generalized total least squares, 313–314, 319–323
definition, 314, 321–322
weighted linear least squares, 303–304, 319–323
definition, 303, 304, 321–322
properties, 303–304, 323, 339–341
simple example, 304–305
weighted nonlinear least squares
deterministic weighting, 627–638
intuitive introduction, 22–23
stochastic weighting, 651–660
well-conditioned, 549
WGTLS
See weighted generalized total least squares
white box models, 17
whiteness test residuals, 445–448, 478–479, 523, 677, 681

Wiener-Hammerstein systems, 85–86
Wiener-Hopf equation, 55, 523
window
half-sine, 63
Hanning, 40
rectangular, 36
windowing
See discrete Fourier transform and frequency response function measurement
Wishart distribution
complex, 569
WLS
See weighted linear least squares

Z
zero-order-hold assumption, 498
measurement example, 504–508
ZOH-assumption
See zero-order-hold assumption