Name Index

Anderson, B.D.O., 17
Athans, M., 24, 33, 84, 116, 118, 119

Baggeroer, A. B., 32, 96, 123, 134, 145, 172
Balakrishnan, A., 120
Battin, R., 23
Bellman, R., 164
Beltyanski, V. G., 84
Bryson, A. E., 56, 63, 122, 127, 134, 161
Bucy, R., 2, 4, 65–66, 122, 169

Capon, J., 41
Chu, L. J., 44
Close, C. M., 8
Collins, L. D., 24, 32, 62, 128, 172
Corbato, F. J., 44
Courant, R., 31

Davenport, W., 3, 10, 22, 59
Delong, D. F., 120
DeRusso, P. M., 8
Desoer, C., 8, 17
Detchmendy, D. M., 164
Delong, D., 120

Everling, W., 171

Faddeeva, V. N., 29, 43, 171
Falb, P., 8, 84
Frazier, M., 56, 63, 122, 127, 134, 161

Gamkrelidze, R., 84
Gray, D., 119

Helstrom, C. W., 23
Hilbert, D., 31
Hinrichs, T. E., 171
Hofstetter, E., 120
Holtzman, J. M., 119
Huang, R. Y., 41

Johnson, R. A., 41

Kailath, T., 38
Kalman, R. E., 2, 4, 65–66, 122, 169
Kelley, E. J., 23
Kennedy, R. S., 120
Kincaid, T. G., 120
Kurtenback, A. J., 31
Kushner, H. J., 2, 29, 156

Landau, H. J., 44
Laning, J. H., 23
Liou, M. L., 29, 43, 170

Meditch, J. S., 168
Middleton, D., 23, 24
Miller, K. S., 23
Mishenko, E., 84
Morse, P. M., 44

Papoulis, A., 131
Pollak, H. O., 44

Pontryagin, L. S., 84
Post, A. E., 48

Ragazzini, J. R., 23
Rauch, H., 56, 63, 122, 132, 134
Root, W. L., 3, 10, 22, 59
Roy, R. J., 8
Rummler, W. D., 120

Schnidman, 199
Schweppe, F. C., 2, 24, 33, 119
Siebert, W. M., 149
Siegert, A. J. F., 34, 78
Slepian, D., 44
Snyder D. L., 2, 9, 156, 161, 167, 169
Spafford, L. J., 120
Sridhar, R., 164
Stratton, J. A., 44
Striebel, C., 56, 63, 122, 132, 134

Titchmarsh, E. C., 32
Titlebaum, E. L., 119
Thompson, J. S., 119
Tufts, D., 119
Tung, F., 56, 63, 122, 132, 134

Van Trees, H. L., 3, 10, 23, 24, 28, 31, 60, 63, 83, 84, 92, 93, 96, 118, 120, 121, 155, 162, 172
Viterbi, A. J., 24

Wiener, N., 2
Weber, C., 120
Wintz, P. A., 31

Youla, D. C., 43

Zadeeh, L. A., 8, 17, 23

Subject Index

Adjoint systems, 20, 130
Ambiguity function, 120
Asymptotic expressions
  eigenvalues of high index, 41
  Fredholm determinant, 34
  large time intervals, 77
  signal design, 85, 91, 94–95

Bandlimited processes, ideal, 44, 52–53
Bandpass process representation, 10, 60, 116, 172–186
  advantage of complex notation for, 177
Bandwidth, 74, 76. *See also* Constraints for signal design
Boundary conditions
  for covariance operator, 21
  for homogeneous integral equations, 27–28
  for inhomogeneous integral equation, 62, 64, 66–67
  for linear smoother, 123
  for minimum principle, 89
  for nonlinear smoother, 168
  for signal design, 91
Butterworth processes
  first-order, 15, 36–37, 72–75, 102–109, 136–140, 153-155, 179–181
  higher-order, 43–53

Calculus of variations, for signal design, 84, 118
Carrier frequency. *See* Bandpass process representation
Characteristic polynomials, 28
Clutter. *See* Detection in clutter
Coefficient matrices. *See* Stability of solutions
Colored noise. *See* Detection in colored noise
Combining signal design solutions, 99
Complex state variables. *See* Bandpass process representation
Continuous time issues, 9, 132
Control functions, 85, 88
Constant parameter systems, 14, 133. *See also* Transition matrices
Constraints for signal design
  amplitude, 81, 83, 87, 118
  bandwidth, 81, 83, 87, 118
  hard amplitude, 119
  hard bandwidth, 114–117
Coupling in nonlinear estimators, 169
Covariance matrix
  process
    complex, 173
    operator, 18–22
    properties, 10–18
  error
    filter with delay, 149–155
    realizable filter, 32, 66, 121, 128, 131–132

Covariance matrix (*continued*)
smoother, 128–134

Degradation. *See* Detection, performance
Delay filtering. *See* Filtering, delay
Detection
in clutter, 60, 82, 119
in colored noise, 3, 5, 57–60, 82
performance, 31, 55, 62–63, 82, 100
bounds, 31, 35
comparison for signal design, 109–110, 113
receivers, 3, 5, 57–60, 82
d_g^2-B^2 (degradation-bandwidth) plane, 101–103, 110
Differential equations. *See also* Covariance matrix
filter with delay, 146
homogeneous integral equation, 27–28
inhomogeneous integral equations, 62
linear smoother, 123
linear realizable filter, 127
nonlinear realizable filter, 168
nonlinear smoother, 163
signal design, 90–91
d^2 (d-squared). *See* Detection, performance
Doppler spread channels, 60, 82, 96, 116–120. *See also* Detection in clutter
Dynamical system description. *See also* Differential equations; Boundary conditions
process generation, 8–11

Eigenfunctions. *See also* Integral equations, homogeneous
expansion for nonlinear filtering, 162
Eigenvalue. *See also* Integral equations, homogeneous
bounds on largest, 28
equation, 26
smallest re signal design, 81, 100, 120
Envelope, complex, 173
Error probabilities. *See* Detection, performance
Errors re smoother error covariance, 134
Estimators. *See* Filtering; Smoothing
Estimator-correlator receiver, 3
Estimator-subtractor receiver, 63, 118

Factorization
spectral, 17, 29
covariance, 18, 19
Faddeeva algorithm, 30, 39, 170–171
Filtering. *See also* Smoothing
delay, 4, 121, 144–155
maximum *a posteriori*, 6, 127, 156–169
nonlinear, 3, 6, 156–169
realizable, 121, 122, 127–128, 163
state variable processes, 2, 4, 6, 32, 67, 122–155, 156–169
stationary processes, 2, 154
unrealizable. *See* Smoothing
First-order processes. *See* Butterworth processes; Wiener process
Fokker-Planck equation, 167
Fourier coefficient, 23
Fredholm determinant, 5, 31–34
Fredholm integral equations. *See* Integral equations
Frequency modulation, 161

Gaussian statistics, 10, 122, 127, 156–157, 161
Global optimality, 96, 99–100, 120
Gradient matrices, 157

Hamiltonian. *See* Minimum principle
Hard constraints. *See* Constraints for signal design
Hermitian matrices, 174, 177

Impulse response for filters and smoothers, 123
Independent increment processes, 9, 130
Integral equations
first kind, 59, 77, 79
homogeneous, 3–5, 23–55
signal design, 81, 93–95
solution properties, 24
inhomogeneous, 3–5, 56–80
smoother solution, 125, 127, 155
solution methods, 63–72
Invariant imbedding, 164–168

Kalman Bucy filtering. *See* Filtering, state variable processes
Karhunen-Loève expansion, 2, 23. *See also* Integral equations, homogeneous

Kellog's method, 31

Lag filtering. *See* Filtering, delay
λ_E-λ_B (energy multiplier-bandwidth multiplier) plane, 100–105, 110
Laplace methods, 30
Likelihood function, 3

Markov processes, 13, 34
M-Ary signals, 120
Matched filters, 77, 102, 107–108
  optimally designed, 108–109
Matrix exponentials, 14, 36, 170–171. *See also* Transition matrices
Means
  Doppler shifts, 180, 183
  process, 123
Minimum principle, 84–96, 118
  Hamiltonian for signal design, 88, 114
  necessary conditions, 88, 114
  stochastic, 118
Modulation operation, 157
  observation equations, 9
Multimodal solutions. *See* Global optimality
Multiple-order solutions. *See also* Minimum principle
  eigenvalues, 29, 41

Nesting, 171
Nonstationary first-order processes, 38–39
Notation, 7
  complex for narrowband processes, 172–173
Number of computations, 80
Numerical methods, 30, 43, 68, 74, 79–80
  stability, 69–70, 100–102

Optimal control theory. *See* Minimum principle
Order function, 32
Orthonormal expansion. *See* Karhunen-Loève expansion
Orthogonality principle, 131

Parameter estimation bounds, 54, 56
  Bhattacharyya, 54
  Cramer-Rao, 54
Pathological solutions, signal design, 94
Performance, improvement by delay, 139, 145. *See also* Detection, performance; Covariance matrix, error
Pontryagin's minimum principle. *See* Minimum principle
Pre-emphasis, 140
Process generation, 8–18
Process representation, impulse response-covariance method, 16. *See also* State variables, description
Prolate spheroidal waveforms, 44

Quasi-linearization, 163

Rank, signal design determinant, 99, 101
Receivers
  detectors in colored noise, 57–58
  detectors in clutter, 57
Reduction, dimension of signal design equations, 92–93
Reverberation, Doppler spread, 60, 82, 96. *See also* Detection in clutter
Ricatti equation. *See* Covariance matrix; Filtering

Scattering function, 120
Second-order processes, 16, 39–43, 75–77, 109–114, 140–144, 180–182
Semidefinite covariances, 26
Signal bandwidth. *See* Bandwidth; Constraints for signal design
Signal design, 5, 55, 81–120
  additive channels, 97–115, 120
  bandpass channels, 119
  Doppler spread channels, 115–120
Singularity functions
  integral equations of first kind, 59, 77, 79
  turn on–turn off, 87
  white noise covariances, 8
Smoothing
  linear, 4, 56, 63, 122–155
  nonlinear, 4, 156–169
Solution methods
  inhomogeneous integral and linear smoothing equations, 63–70
  nonlinear smoothing, 162–163
Stability of solutions, 69–70, 131, 132, 149, 155

State variables
  complex. *See* Bandpass process representation
  covariances, 10–18
  descriptions, 8–11
    initial state, 9
    observation equation, 9
    state equation, 9
    state vector, 9
  random processes, 8–18
  solution
    homogeneous integral equation, 24–31
    inhomogeneous integral equation, 62–70
Stationary processes
  constant parameter systems, 14
  narrow-band processes, 172
  rational kernels, 26
  spatial covariances, 14
Structual approaches, 10, 122
Suboptimal solutions, signal design, 105
Sufficient statistics. *See* Receivers
Superposition method, 64, 163
Symmetry, optimal signals, 105, 107

Tupped delay lines, 149
Time-bandwidth products, 34, 39, 41, 119, 171
Time varying coefficients, optimal smoother, 127, 134
Tracking, signal design for, 119. *See also* Smoothing
Transition matrices
  definition, 12
  matrix exponentials, 14, 30, 101, 170–171

Unstructured Gaussian approaches, 10, 122

White noise, 8, 59, 161
Whitening filters, 128–130
Wiener filtering. *See* Filtering, stationary processes
Wiener-Hopf equation, 3, 56, 121, 123, 155
Wiener process, 15, 35–36, 70–72, 134–135