

Index

- 3GPP (The 3rd Generation Partnership Project), 24, 35, 91, 107, 111–12
- 802.11, 35, 240
- acquisition time, 95–6, 259–60, 263
 - average, 95–6
 - distribution, 95
- ADC (analog to digital converter/conversion), 16, 28, 92, 168, 177, 255
- ADPLL (all-digital PLL), 132, 147
- AFC (automatic frequency control), 186, 220, 253
 - VCO-based implementation, 254–5, 257
 - XO based implementation, 256–9
- AGC (automatic gain control), 67, 135, 185
- analog signal reconstruction, 324, 371
- AP (access point), 45, 120, 127, 263
- APLL (analog PLL), 132, 136, 141
 - first-order, 333, 335–6, 339
 - second-order, 138, 140
 - transfer function, 137, 139
 - type, 139–40
- autocorrelation function, 75, 366
 - impulse, 88–90
 - periodic, 90–1
- AWGN (additive white Gaussian noise), 15, 17
- bandwidth, OFDM, 39, 46, 231
 - data, 39, 113, 116
 - DFT, 37, 49, 232
- baseband signal samples, 2, 40, 193, 203, 256, 267, 318
- baseband signal waveform, 2–3, 8–9, 14
- bias, DPLL output, 153, 155, 162, 174
- carrier frequency offset, 15, 32, 88, 196
 - detection, 28, 31
- carrier frequency offset estimation, OFDM, 243, 246
 - post-DFT/FDM pilot assist, 246–8, 265
 - pre-DFT/CP correlation, 116, 264–5, 315
- carrier frequency synchronization, 24, 203, 211, 215
 - DPLL implementation, 220
 - for OFDM communication, 229, 236, 243, 264, 268
 - in cdma2000–1x receivers, 260
 - in wireless receivers, 253–4
- carrier phase correction
 - feedback, 210
 - feed-forward, 209
- carrier phase detection, 204, 209
 - data assisted, 205–6, 251
 - non-data assisted, 216, 218, 278
- carrier phase estimate, 217
 - approximate ML, 206, 267
 - ML, 206, 208, 267
- carrier synchronization, 220
 - baseband signal samples, digital processing, 193, 196, 203–28, 267
 - OFDM, 228–48
 - passband signal, analog processing, 193, 196–203, 267
 - wireless, 188–9, 251–60
 - wireline, 135, 185, 248–51, 268
- CAZAC (constant amplitude zero autocorrelation) sequences, 91
- channel coding, 4–5, 19, 197, 202, 210, 217
 - gain, 4–5
 - rate, 108, 271
- channel modulation symbol, 7–8, 11, 18, 24, 69, 108
 - see* channel symbol
- channel symbol, 8, 22–3, 98
 - interval, 69, 271
 - rate, 17, 22–3, 180, 294, 341
 - sequence, 9
- channel, fading, 189, 255, 262
 - fast fading, 13, 221
 - Jakes model, 14
 - slow fading (shadowing), 13
- channelization codes, 108
- characteristic polynomial, 89, 102, 117
- chip, CDMA, 30, 33, 102
 - frequency/rate, 276
 - interval/duration, 49, 106, 260, 295, 302, 365
 - pilot, 260, 294, 296–7
 - sequence, 27, 293
- chirp sequence, 90–1
- chi-square distribution
 - central, 77, 84, 123
 - non-central, 77, 84

- CIR (channel impulse response), 3, 58
 - coefficients, 73, 79, 288, 291–2
- coherence bandwidth, 229, 231
- coherence time, 71, 235, 247
- coherent combining, 71, 80, 118 *see* coherent integration
- coherent communications, 19, 23, 195
- coherent integration,
 - length, 76, 80, 96–9, 105, 110
 - loss of, due to frequency offset, 82, 98, 128, 262
- common pilot chip sequence, 294
- complex signal, 287, 325
 - in-phase (I) component, 11, 102
 - quadrature (Q) component, 11, 102, 207
- composite decision metric, 71
 - noncoherent, 76, 83–4, 87, 99, 110
- constellation points, 6, 19–20, 195, 202
- continuous pilots, 242, 260, 262
- continuous-time CIR, 12, 79
- correlation
 - aperiodic, 88, 90–1, 98, 109, 116
 - periodic, 88
- correlation-and-accumulation, 122, 125, 240
- Costa loop, 199–200
- CP (cyclic prefix), OFDM, 36, 243
- CP, LTE,
 - extended, 114, 117, 266
 - normal, 113, 117–18, 265, 317
- Cramer–Rao bound, 52, 59–61, 66, 81, 128, 206, 267
- cyclostationarity, 251, 267, 278
- DAC (digital to analog converter/conversion), 2, 9, 11, 174, 194, 364
- damping behavior, PLL, 157–8
 - critically damped, 158, 161–2, 165, 178, 304
 - damping factor, 139–42, 145–6, 158–65, 169, 182–3, 190, 304
 - over-damped, 144–5, 158, 162, 164, 304
 - under-damped, 161–2
- data symbol, 7, 36, 49
 - interval, 221, 271
 - rate, 25–6, 103, 108, 207
- data symbol constellation, 7, 19–20
 - AM, 6, 196
 - BPSK, 6, 8, 19, 73, 198
 - MPSK, 6, 8, 200–1, 218
 - QAM, 6–8, 20, 200, 202–3
 - QPSK, 6, 8, 19, 73
- DCO (digital-controlled oscillator), 148–9, 174
- decimation, 116, 327, 332 *see* down-sampling
- decision, hypothesis testing, 61–3, 66, 77
 - metrics, 71, 76, 83
 - rule, 52, 61–6, 77–8
 - threshold, 52, 63, 78
- deinterleaving, 14, 20, 106
- delayed update, PLL, 211, 250–1
- despreading, 25, 106, 263, 293, 297
 - processing gain, 275, 293, 301
- detected symbol, 71, 74, 80, 99
- DFT window, 40, 44, 244, 307
 - CP region, 244, 305–6, 309, 316
 - position, 40, 44, 46, 229, 235, 305, 308, 317
- DFT, OFDM demodulator, 36, 42
- digital interpolation, 31, 322, 324, 326, 328, 332, 372
 - broad sense, 327
 - narrow sense, 327, 329
 - up-sampling, 328
- digital rate conversion, 324, 327–8, 357
 - by an arbitrary factor, 332
 - down-conversion, 327
 - rational, 332
 - up-conversion, 327
- digital resampling, xvii, 17, 186, 258, 322, 324, 365, 368, 371
- DLL (delay locked loop), 186, 295
- Doppler, 13, 36, 248, 253
 - frequency shift, 13, 120, 261, 265–6, 276
 - spectrum, 14, 239
- down-conversion frequency, 15, 23, 168, 195, 204, 236, 243
- down-sampling, 180, 332, 342, 369
- DPLL (digital PLL), 132–3, 147–8
 - first-order, 147–51
 - multi-rate, 181–2
 - second-order, 147, 155–7, 161
 - transfer function, 151, 157
- DSB/SC (double-sideband/suppressed-carrier modulation), 197, 199–200
- DVB-T (European digital terrestrial television standard), 35, 239, 241–2, 315
- Early-Late (E-L) gate algorithm, 280, 282, 286, 318
 - data-assisted, 284–5, 318
- echo cancellation, 322, 324, 350, 362–4
- echo canceller, 362
- equivalent baseband channel, 3, 14, 58
- equivalent input noise, 212, 223, 226
 - DPLL, 212
 - QCFD, 226
- excess bandwidth, 73, 278, 297, 341, 348, 366
- excess delay, OFDM channel, 306–7, 320
- FAP (first arriving path), 230, 309, 316, 320
 - backoff, 306–7, 309, 316
- Farrow’s architecture, 353–4, 360
- Farrow’s delayer, 350–1, 353, 355, 359, 372
- FC (frequency controller), 186, 221–2, 255
- FCE (frequency domain channel estimate), 308, 314, 316
- FD (frequency detector), 186, 213, 221, 254, 257, 261
 - MLFD, 213, 268
 - QCFD (Quadri-Correlator FD), 214–15

- squaring FD, 219–20
- Squaring QCDF, 219–28
- FDD (frequency division duplex), 113, 115, 119
- FDM (frequency-division multiplexed) pilot,
 - OFDM, 45–6, 231, 245, 263
 - continuous, 47, 242
 - scattered, 47, 242–3
 - staggered, 232, 236, 246
- FEC (forward error correction), 4–5
- finger management, 29, 300–1, 319
- FIR interpolation filter design, 341, 346, 348
 - “don’t care” regions, 342–3, 345–8
 - equal-ripple, 344–5
 - passband, 345–6
 - Stopband, 340, 342–9, 372
 - transition band, 340, 342, 346–8, 372
 - WLS (weighted least squares), 345
- firls*, WLS FIR filter design routine, 346–8
 - input parameters, 346
- Fisher Information, 60
- FLL (frequency locked loop), 186, 203, 207, 220
- forward link, 1, 25, 108
- frame synchronization, 21, 52, 68, 361
- frequency binning, 98–9, 259
 - implementation, 259
- frequency domain characteristics, PLL,
 - 3dB bandwidth, 141, 151, 159–60
 - noise bandwidth, 141–2, 151–2
 - roll-off, 138, 142, 180
 - single-sided, 152
 - two-sided, 152, 160
- frequency domain interpolation, 233–4
- frequency domain sampling, 231
- frequency down-conversion, 14, 41, 168, 175, 187, 203, 254
- frequency down-converter, 15, 72, 135, 204
- frequency spur, 42, 68, 229
- frequency synthesis, 132, 135, 186, 188
- FSE (fractionally spaced equalizer), 275, 280, 283, 288–9
- FTL (frequency tracking loop), 220
- FD gain, 221
 - MLFD, 214
 - QCDF, 215
 - Squaring QCDF, 220
- Gardner algorithm, 282–3, 286
- Gaussian distribution, 62, 92, 225 *see also* normal distribution
- GI (guard interval), OFDM, 38, 46, 121
- GPS (Global Positioning System), 102, 188, 258
- Hadamard code *see* Walsh code
- hypothesis test, 57
 - detection probability, 61, 66, 72, 78, 128
 - false alarm probability, 61–3, 66, 72, 78, 85, 92, 128
 - miss probability, 61, 72, 85
 - hypothesis test, binary, 61–2, 66
- i.i.d. (independent and identically distributed), 55, 73, 81, 84
- IAD (integrate-and-dump), 181
- IBFD (in-band full-duplex), 362
- ICI (inter-(sub)carrier interference), 35, 236–7, 310, 320
- ideal delay, 326, 353, 355
- iDFT, OFDM modulator, 36–8
- initial acquisition, xvii, 16, 21, 41
 - general detection process, 72–6
- initial acquisition, 70–2, 74, 83
 - 802.11a/g, 120–6
 - IS-95/cdma2000–1x, 101–7
 - LTE, 46, 112–20
 - WCDMA, 107–12
- initial frequency offset, 46, 97, 259, 262, 264
- initial frequency offset estimations, 802.11a/g, 240, 253, 263
 - coarse, with short preamble, 124, 240, 263
 - fine, with long preamble, 263–4
- initial system acquisition, 120, 127, 313
- integrator, perfect, 137, 139–40, 150, 221, 283, 299, 303
- interleaving, 5
 - block, 6
 - convolutional, 6
- interpolation
 - 0th-order, 333, 335–8, 372
 - first order *see* interpolation, linear
 - high order, 340
 - linear, 233, 336–7, 340, 351–2, 356, 365–7, 369
- interpolation filter, ideal, 340, 343
 - interpolation formula, 325
- intra-cell interference, 93, 293
- ISI (intersymbol interference), 12, 74, 76, 229, 305
- ISI channels, 275, 284, 287, 290, 319
- ISI-free channel, 17, 292
- Lagrange interpolation, 351, 365
- Lagrange interpolator, 352, 354, 356, 371–2
 - DLL implementation, 167–77
 - Farrow’s architecture, 353–4
 - maximally flat response at zero frequency, 353, 355
 - third-order, 353, 367
- LE (linear equalizer), 18
- likelihood, 19
- likelihood function, 52–3, 56, 58, 60, 63, 65, 70, 273
 - continuous-time signal, xvii, 56
 - unconditional, 64
- linear phase change *see* phase ramp
- LO (local oscillator), 15, 21, 29, 67, 186, 248–9, 253
- log-likelihood, 19, 54, 70, 73

- log-likelihood function, 52–6, 58, 64, 69, 272
 - carrier phase, 204
 - timing phase, 272–4
- log-likelihood ratio (LLR), 19–20, 30, 54
- long preamble, 802.11a/g, 45, 121, 241
 - channel estimation based on, 46, 124–5
 - symbols, 45, 121, 124–6, 313
- loop coefficient, DPLL, 133–4, 147–8, 167, 174, 178–9, 190, 200, 249
 - first-order, 148
 - second-order, 156
- loop filter, digital, 147–8, 156, 178
- loop filter, analog, 136–40
 - active, 140, 144
 - passive, 138–9
- loop gain, PLL, 139, 158, 182
 - DC, 138
 - first-order, 138, 154, 157, 161, 163, 169, 304
 - second-order, 157, 169, 277, 304
- LS (least squares) estimation, OFDM FCE, 233, 344–5
- LS interpolation, OFDM FCE, 233
- LFSR (linear feedback shift-register), 89
 - Fibonacci configuration, 89
 - Galois configuration, 89
- LTE (Long-Term Evolution), 112
- MAP (maximum a posteriori), 52, 59, 66
- mapping, DPLL to APLL, 147, 160, 166, 190
 - approximate derivative method, 164, 166
- maximum ratio combining, 33
- MF (matched filter), 16, 204, 273
 - approximate, 16, 267
 - of composite channel *see* MF of the received signal
 - of the received signal, 58, 204
- midamble, 252, 291
- ML (maximum likelihood), 19, 52, 128, 267
 - estimation, 19, 52, 55, 65
- MLPD (maximum likelihood phase detector), 208–9, 217, 219, 221, 225, 227, 268
- MLSE (maximum likelihood sequence estimator), 18, 291
- MMSE (minimum mean squared error), 34, 60, 232
- MMSE estimator, 233
- modified Bessel function of the first kind
 - of an integer order L , 84
 - of zeroth order, 64, 70
- modulation frequency, 15, 213
- modulator, 11, 72
- monitored set, 301
- m-sequence (maximum-length shift register sequences), 88–9, 98, 102, 109, 117
 - LFSR realizations, 89
- Mueller–Müller algorithm (M-M algorithm), 284–5, 318
- multi-dwell search, 90, 96
- multi-mode receiver, 368
- multisystem environment, 368, 372
- multipath channel, 13, 27–8, 30, 33, 69, 80, 290
 - path coefficient, 44, 260–3
 - path delay, 30–1, 247, 301
 - path, resolvable, 30, 301
- multistage training, PLL, 182–3
- NCO (numerically controlled oscillator), 174
- Neyman–Pearson lemma, xvii, 52, 61, 71, 78, 93, 128
- node-B, 111–12, 120, 262, 294
- noise variance estimation, 87, 91, 129
 - in medium to high SNR environments, 92–4
 - in noise/interference dominated environment, 92
- noncoherent combining, *see* noncoherent integration
- noncoherent communication, 19
 - DPSK modulation, 195
 - orthogonal modulation, 195
- noncoherent integration, 71, 80, 83, 98, 105, 128
 - length, 76, 79–80, 83, 97–9, 105
 - loss, 86, 97, 116, 128
- noncoherent reception, 195
- nonfrequency selective channel, 68, 128
- nonlinear processing, 197, 215, 267, 278
- normal distribution, 76–7, 81, 84, 123
- NPLL (numerical PLL), 133
- Nyquist criterion, 194, 205–6, 267, 274, 284, 286, 293
- Nyquist frequency, 342, 346–8, 369
- Nyquist sampling rate, 16, 22, 180, 324–5, 357, 371
- Nyquist sampling theorem, 40, 324–5, 371
- OFDM carrier frequency offset, 229
 - fractional offset, 237
 - impact on receiver performance, 236–7, 239
 - integer offset, 237
- OFDM carrier frequency offset detection, 239, 241, 246
 - CP based, 243, 245, 247
 - detection range, 245–8
 - FDM pilot based, 241, 243, 246
- OFDM carrier phase synchronization, 228
 - subcarrier phase estimation, 229
- OFDM channel sample, 39, 49, 113, 243, 313
 - interval, 122, 305, 325
 - rate, 37, 240, 275
- OFDM symbol, 35, 40
 - CP, 36, 38, 243–4, 306, 314
 - interval, 47, 49, 317
 - main portion, 38–9, 41–2, 113, 244, 305
 - rate, 49, 231, 265
- OFDM timing synchronization, 312, 368
 - optimal timing phase selection, 305
- overall channel, 17–18, 22, 194–5, 278, 280, 284
- PAPR (peak-to-average ratio), 90, 115
- parallel-to-serial conversion, 37
- PD (phase detector/phase error detector), 133, 136, 167, 176, 187

- PD, nonlinear,
 *M*th power, 218
 sign-error, 170
 squaring, 216–17, 219, 227
 squaring QPD, 217–18
 penalty, initial acquisition, 96
 due to P_F , 96
 due to P_{miss} , 96
 phase controller, PLL, 133–4, 148, 174
 all-digital, 147, 172, 174, 176, 181
 gain, 137, 149, 169, 175–6
 VCO based, 137, 148, 172, 174, 181
 phase error, steady-state, 134–5, 138, 150, 153–4, 156, 162
 phase ramp, 134, 138, 143
 phase rotator, digital, 176, 181, 222
 PHY (physical layer), 22, 101, 106, 112, 121, 127
 PLCP (Physical Layer Convergence Procedure), 121
 pilots, 7, 36, 45, 221
 burst, 69, 231, 252
 continuous, 69, 231, 252
 PLL (phase locked loop), xvii, 131–2, 189
 transfer function, 134, 136, 138–9, 150, 157
 PLL, mixed-signal, 131–2, 147
 PN (pseudo-noise), 27, 88
 PN sequences in cdma2000–1x, 46, 88
 long PN sequence, 102–3
 short PN sequences, 98, 102–5, 294
 Poisson summation formula, 278
 Polyphase filter bank, 328, 330, 333, 335, 350
 FIR, 324, 331, 340, 355, 358, 372
 IIR, 328
 subfilters, 340–1
 post-detection integration/combining, see non-coherent integration
 PPDU (PLCP protocol data units), 121, 125
 ppm (parts per million), 97, 177
 pre-detection integration/combining, see coherent integration
 pulse shaping, 4, 8–9, 11, 194, 271

 QPD (quadrature phase detector), 207, 211
 gain, 208, 211
 phase detection range, 208
 queue depth monitor, 357, 361

 RAKE receiver, 28–9, 34, 106, 293, 319
 demodulation block, 31–2
 optimality, 33–4, 206
 synchronization block, 31–3
 RAKE finger, 28, 30–1
 rate conversion with polyphase FIR filter bank, 328–40
 distortion analysis, 337–9
 first-order interpolation, 336
 zero-order interpolation, 335
 rate conversion, digital, 2, 324, 328, 332, 357, 362

 rate converter, digital, 328
 RCOS (raised-cosine), 17, 28, 30, 69, 274, 284
 receiver filter, 16–17, 34, 204
 receiver sleep state, 276, 290
 reference symbol sequence, 69, 71, 74, 80, 88
 reverse link, 1
 RF spurs, 187, 368, 372

 sampling time advance, 328, 332, 335, 355
 sampling time delay, 260, 327–8, 350, 355–6
 scrambling sequences, 27, 111–12
 S-curve, 208, 285–6, 298
 serial-to-parallel conversion, 41
 SFN (single frequency network), 316
 Shannon channel capacity, 5, 35
 short preamble, 802.11a/g, 45
 frequency offset detection, 124, 240
 signal detection, 123, 125, 240
 symbols, 45, 121, 125, 240, 313
 symbol constellation point, 6–7, 19–20, 194–5, 202
 symbol sequence,
 orthogonal, 25, 69, 88
 uncorrelated, 25, 69, 88
 SICiR (signal to ICI ratio), 310–12, 316
 sinc function, 9
 single-carrier communications, 4, 7–8, 24–5, 35, 49, 168, 229, 267, 341
 single-path channel, 42, 59, 76 see nonfrequency selective channel
 spectrum shaping, 8–9, 194
 speech activity factor, 25
 SPL (software PLL), 133–4
 spread spectrum,
 quadrature spreading, 102–3
 spreading factor, 25, 49, 108
 spreading sequence, 24–5, 103, 252, 262
 squaring loss factor, 198
 SRCOS (square-root raised cosine) spectrum, 9, 59, 69, 297
 SRE (symbol rate equalizer), 275, 288, 292
 timing phase selection, 275, 280, 285, 288, 319
 standard time unit, LTE, 49, 113
 subcarrier, OFDM, 35, 37, 47, 114, 120, 230, 232
 data subcarrier, 36, 114, 230, 232, 311, 315
 guard subcarrier, 37, 40, 113, 232
 pilot subcarrier, 46–7, 230–2, 234, 242, 247, 263, 315–16
 subcarrier coefficients estimation, 119, 230, 232, 234
 subcarrier coefficients interpolation, 235, 247
 subcarrier spacing, 37, 40, 49, 231, 239–43, 246
 subfilters, FIR filter bank, 328, 331
 mean of passbands, 343
 MSE of passband variation, 344
 synchronization channels (SCH), WCDMA, 108
 P-CPICH (primary common pilot channel), 108–12, 263, 294

- synchronization channels (SCH), WCDMA (cont.)
 - P-SCH (primary SCH), 109–12
 - S-SCH (secondary SCH), 109–12
- synchronization channels, cdma2000
 - pilot, 26, 28, 102–6
 - synch, 102, 104–7
- synchronization, GSM, 290
 - synch word, 291–2
 - TSC (training sequence code), 291
- synchronization signals, LTE, 114, 241
 - acquisition, 114–20
 - PSS (primary synchronization signal), 46, 114–20, 241, 264, 313, 315
 - SSS (secondary synchronization signal), 46, 114, 117–20, 241, 264, 313, 315
- TCL (timing control loop), 23, 186, 276
- TDD (time division duplex), 113, 120
- TDM (time-division multiplexed) pilot, 93, 290, 362
- time-domain channel coefficient, 233, 235, 265
- time-frequency grid, 46, 231
- timing control by digital rate conversion, 356–7
 - cdma2000–1x receiver, 365–6
 - echo/self-interference cancellation receiver, 361
 - LTE/WCDMA dual-mode receiver, 368–70
- timing discriminator function, 280, 282, 284, 286, 297
- timing frequency offset, 29, 276–7, 303
 - performance impact on OFDM receiver, 309–13
- timing frequency synchronization, 275–6
- timing phase estimation, 285, 295
 - approximate ML, 273, 278, 318
 - ML, xvii, 272–3, 318
- timing recovery, 22, 271
- timing synchronization, xvii, 21–3, 271, 276, 318, 321
 - CDMA, 293
 - channel/equalizer coefficient estimates based, 287, 290
 - data/decision-assisted, 283
 - non-data assisted, 284
 - squarer based, 278–80
 - wireless, 253
- timing synchronization, all-digital implementations of, 322, 327, 357
- timing synchronization, OFDM, 304–18
 - window positioning, 44, 124–6, 275
- TLL (timing locked loop), 23, 186, 276–7, 322, 357
 - all-digital implementation, 277, 357–8, 360–1
 - analog, 276
 - mixed-signal, 276
- TPC (timing phase controller), 186, 276, 295, 303, 358
 - VCO-based, 277, 322
 - with digital resampler, 358–60
- TPD (timing phase detector/timing phase error detector), 186, 276–7, 301
- transitional response, PLL, 141, 143, 166
 - to linear phase change (phase ramp), 143–4, 146, 154, 162–3
 - to step phase change, 143–5, 147, 152, 160
- transmitter filter, 11, 15, 27, 34, 193, 319
- TTL (timing tracking loop), 186
- UE (user equipment, 3GPP), 111, 264, 315
- UMMSE (unbiased MMSE), 61
 - UMMSE estimator, 60
- UMTS (Universal Mobile Telecommunications System), 98, 107, 112, 262
- unbiased estimate, 19, 60
- unbiased estimator, 59, 66, 81
 - efficient, 60–1
- unit step function, 143, 153
- up-conversion, 187
- up-sampling, 329, 331–2
- VCO (voltage-controlled oscillator), 133–4, 136–7
- Walsh code, 26–7, 103, 108, 261
- Walsh covering, 102–3
- Walsh functions, 26–7
- Wiener filter, two-dimensional, 232
- Wi-Fi see wireless LAN
- wireless LAN (local area network), 35
- XO (crystal oscillator),
 - DCXO (digital controlled XO), 186, 254
 - VC-TCXO (voltage-controlled temperature-compensated XO), 97, 133, 136, 254, 258
 - VCXO (voltage controlled XO), 174
- Zadoff–Chu sequence, 91, 115, 129
- zero-inserted sample sequence, 329, 342, 348