

# INDEX

- Absorber, 7
- Acoustic bandwidth, 159, 162
- Acoustic convolver, 294–311
  - using waveguide, 305–311
- Acoustic potential, 73, 74
- Acoustic waves, 1, 19–37
  - in anisotropic materials, 29–37
  - in isotropic materials, 19–29
  - see also** bulk waves, longitudinal waves, shear waves, surface waves
- Active correlator, 284, 316
- Active electrodes, 85
- Active generation, 218, 242
- Admittance:
  - of transducer, 77, 89–95, 98
  - of chirp transducer, 235, 236–239
- Admittance matrix of device, 104
- Ageing of oscillators, 322
- Air loading, 144
- Aliasing, 189, 340
- Aluminium layer:
  - effect on surface waves, 26, 147, 150, 154
  - resistivity of, 167
- Aluminium nitride, 155, 287
- Aluminium phosphate (berlinite), 154
- Amplification, 54
- Amplitude-modulated waveform, 190, 191, 192, 338
  - sampling of, 191, 339–341
- Angular spectrum of plane waves, 132–134, 140
- Anisotropic material:
  - elasticity in, 15–19
  - layered, 36–37
  - orientation of, 30
  - waves in, 29–37
  - see also** materials
- Apodisation loss, 103
- Apodised transducer, 8, 61–64
  - admittance of, 98
  - delta-function analysis, 61–64
  - design of, 63, 192–200
  - frequency response, 99–100, 387–390
  - impulse response, 9, 63
  - as transversal filter, 185–187
  - see also** interdigital transducer
- Applications, 13
  - for chirp filters, 9, 213, 216, 218, 268, 277–279
  - in pulse-compression radar, 9, 214–219
  - in spread-spectrum communications, 283, 291, 293, 294, 299
  - in television, 14, 207, 208
  - see also** channelised receiver, compressive receiver, Fourier transform systems, frequency hopping, frequency measurement, frequency-shift keying, frequency synthesis, minimum-shift-keyed waveforms, oscillator
- Array factor, 59, 85, 99
  - for gap elements, 89, 100
- Attenuation, in convolvers, 302
  - see also** propagation loss
- Auld's reciprocity relation, 344
- Bandpass filter, 9, 183–211
  - bank of, 126, 209–211, 294
  - using bulk waves, 4, 399–401
  - using chirp transducers, 209, 244
  - circuit effect in, 204–205
  - using crystal resonator, 4
  - design of, 192–200, 205–206
  - equi-ripple, 198
  - L–C type, 183, 207, 208
  - minimum phase, 199–200
  - monolithic crystal filter, 4
  - using multi-phase transducers, 176

- with multi-strip coupler, 124–126, 203
- performance of, 206–208
- using reflective array, 209
- using resonator, 4, 209, 321
- second-order effects in, 205–206
- using surface-skimming bulk waves, 399–400
- types of, 203, 208–209
- variable, 277, 278, 313
- using zinc oxide, 55, 208
- Bandpass waveform, 188, 189, 190, 221, 337–341
- Bandstop filter, 278, 401
- Barker code, 299
- Beam compression, 126–127, 306
- Beam forming, 277
- Beam steering, 43, 134–136, 139, 151
- Berlinite, 154
- Bilinear device, 296, 309
- Bilinearity factor, 301, 302, 303
- Bismuth germanium oxide, 36, 154, 267
- Bleustein-Gulyaev wave, 34, 36, 46
- Bragg cell:
  - using bulk waves, 131
  - using surface waves, 6
- Broadcasting, *see* television
- Bulk waves, 2
  - in chirp filters, 242, 398–399
  - devices using, 2–4, 219, 394, 399–401
  - and effective permittivity, 46, 396–397
  - and Green's function, 51
  - and interdigital transducers, 66, 80, 153, 393–401
  - mode conversion of, 397–399, 401
  - and multi-strip coupler, 118, 119, 398
  - in reflective array compressor, 264, 399
  - surface-skimming, 399–400
  - in surface-wave devices, 393–399
  - see also* longitudinal wave, plane wave, shear wave
- Bus-bar, 57
- Cadmium sulphide, 34
- Capacitance of transducer, 77, 87, 93–95, 238
- Cascading, 172, 317
- Causality, 78, 199, 334
- Ceramics, 154, 301
- Channels, 97
- Channelised receiver, 210
- Charge-coupled device, 187, 268, 315–316, 317
- Charge density, 40, 41, 44, 50
  - acoustic, 69, 73
  - electrostatic, 40, 41, 69–72, 76
  - evaluation of, 72
  - elemental (for electrodes), 84–87, 358–360
  - elemental (for gaps), 89, 185
  - in quasi-static approximation, 69
- Charge superposition, 71, 88
- Chips, 283
- Chip rate, 286
- Chirp filter, 9–11, 213–279
  - bulk waves in, 242, 398–399
  - using bulk waves, 219, 394
  - design of, 241–244
  - diffraction in, 144, 256
  - double-dispersive, 243–244
  - for frequency synthesis, 293
  - group delay of, 222, 231
  - matched pair of, 219, 242, 244, 252
  - optical counterpart, 279
  - performance of, 244
  - second-order effects in, 247–252, 255–256
  - short-circuit response, 235
  - for signal processing, 268–279
  - single-dispersive, 241–242
  - technologies for, 219, 394
  - temperature effects in, 250–252
  - transmission-line effects in, 256
  - variable, 278
  - weighting of, 224–231
  - see also* chirp transducer, chirp waveform, compressive receiver, compressor, expander, pulse-compression radar, reflective array compressor
- Chirp rate, 220
- Chirp transducer, 231–241
  - admittance of, 236–239
  - analysis of, 233–239
  - in bandpass filter, 209, 244
  - capacitance of, 235, 238
  - conductance of, 235, 236–239
  - in convolver, 306
  - delta-function analysis, 235
  - design, 239–241
  - effective number of periods, 237–238
  - frequency response, 234–235
  - Q-factor, 238–239
  - and sampling, 233, 235, 335
  - scattering coefficients, 235
  - second-order effects in, 247–252, 255–256
  - slanted, 243, 398
  - transmission-line effect in, 256
  - see also* chirp filter, chirp waveform
- Chirp transform, 271
- Chirp waveform, 215, 217–231
  - active generation of, 218
  - bandwidth of, 223
  - doppler effect, 218, 252–255

- down-chirp, 220
- linear, 218, 220, 222–229, 254
- non-linear, 218, 229–231, 254
- passive generation of, 218, 242
- phase errors in, 247–255
- reciprocal-ripple design, 228, 231
- sampling of, 191, 233, 235, 239, 335–337
- spectrum of, 221–223
- stationary-phase analysis, 221–224
  - limitations of, 223, 228, 231
- up-chirp, 220
- weighting of, 224–227, 229–231
- weighting functions for, 226–227
- see also** chirp filter, instantaneous frequency, pulse-compression radar, time-sidelobes
- Circuit effect, 65, 100, 162
  - in bandpass filter, 204–205
- Circuit factor, 102, 104
- Code, **see** Barker code, pseudo-noise code
- Communications, 14
  - spread-spectrum, 11, 14, 281, 282–285
- Complex envelope, 337
- Compression ratio, 10, 216
- Compressive receiver, 14, 268–277
- Compressor, 216
  - see also** chirp filter
- Conductance:
  - of transducer, 77, 89–93
  - of chirp transducer, 235, 236–239
- Conversion coefficient, 81, 169
- Conversion loss, 164, 169
  - and triple transit, 169
  - see also** insertion loss
- Convolution, 297, 298, 327, 331
  - see also** convolver
- Convolution theorems, 327
- Convolver, 281, 294–316
  - acoustic, 294–311
    - second-order effects in, 302–304
    - using waveguide, 305–308
  - with air gap, 313–315
  - attenuation in, 302
  - with beam compression, 306, 307
  - bilinearity factor of, 301, 302, 303
  - cascaded, 317
  - with chirp transducer, 306
  - degenerate, 296, 297
  - diode, 300, 312–313
  - dispersion in, 303, 305, 306
  - dynamic range, 308, 309
  - efficiency, 300–301, 305, 308
  - fidelity, 309–311
  - fold-over convolution in, 303–304, 307, 309
  - frequency response, 309–310
  - ideal, 302, 310, 311
    - as matched filter, 298–300
    - non-degenerate, 296, 298, 304
    - propagation effects in, 302–303
    - with repetitive reference, 300
    - saturation in, 302, 306, 313
    - second-order effects in, 302–304
    - using semiconductor, 54, 312–316
    - for signal processing, 294, 297, 299, 312, 313
    - spatial response, 310–311
    - spatial uniformity, 304, 307, 310–311
    - with storage, 314–316
    - temperature effects in, 303
    - and time-reversal, 300
    - transmission-line effect in, 304, 307
    - using waveguide, 305–311
    - using zinc oxide, 314, 315
- Correlation function, 288, 334
  - see also** matched filter
- Correlation of long waveforms, 316–318
- Correlation peak, 216, 284, 289, 290
- Correlator, integrating, 317
- Coupled-wave analysis, 108, 146, 264
- Coupler, **see** multi-strip coupler
- Crossed-field model, 66, 375
- Cross-overs, 173, 175
- Crystalline material, **see** anisotropic material, materials
- Crystal oscillator, 3, 318, 321
  - see also** oscillator
- Crystal resonator, 3, 29
- Cut, 31
- Delay line, 7, 123, 124, 157–173
  - using bulk waves, 2–3
  - cascading, 172
  - disk, 172
  - dispersive, 9, 29
    - see also** chirp filter
  - ideal, 331
  - for long delay, 124, 172
  - in oscillator, 318
  - in recirculation loop, 317–318
  - strip, 219
  - tapped, 11, 172
    - see also** PSK filter
  - variable, 277, 278
  - wrap-around, 172
- Delta function, 327, 335
- Delta-function model, 57–64, 89, 100
  - for chirp transducer, 235
- Differentiation theorems, 326
- Diffraction of light, 6, 130, 131
- Diffraction of surface waves, 132–144

- anglar-spectrum-of-plane-waves analysis, 132–134
- compensation for, 206, 256
- and design, 191, 200, 209
- in far-field region, 139
- Green's function analysis, 132, 139
- minimal-diffraction orientations, 136–137, 153, 154
- in multi-strip coupler, 118
- in parabolic approximation, 137–140, 151
- scaling, 137, 139, 151
- for two transducers, 140–144
- Digital filter, 187, 193, 197
- Digital processing, 219, 268, 276, 277
- Diode convolver, 300, 312–313
- Disc delay line, 172
- Dispersion of surface waves:
  - in chirp filters, 252, 264
  - in convolver, 303, 305, 306
  - due to film (layer), 26, 27, 36, 154, 155
  - on "free" surface, 146
  - in regular electrodes, 368–369
  - see also** stored energy
- Dispersive delay line, 9, 29
  - see also** chirp filter
- Displacement, acoustic, 15
  - for Rayleigh wave, 23, 32, 33
- Dolph-Chebyshev window, 196, 227
- Doppler effect, 252–254
  - for chirp waveforms, 254–255
  - for PSK waveform, 290
- Doppler shift, measurement of, 277
- Dots, 209, 267
- Double-electrode transducer, 65, 89
- Dougall's expansion, 357
- Down-chirp waveform, 220
- Driving networks, 174, 179–180
  - see also** matching
- Dummy electrodes, 97, 232
- Dynamic range, of convolver, 308–309
  
- Earthquakes, 2
- Echo trap, 124
- Effective permittivity, 41, 44–49
  - for Bleustein-Gulyaev waves, 46
  - and bulk waves, 46, 396–397
  - Ingebrigtsen's approximation, 48, 52
  - and launching transducer, 351–353
  - for lithium niobate, 46
  - for piezoelectric layer, 55
  - for plane above surface, 52–53
  - symmetry of, 348
- Elastic waves, **see** acoustic waves
- Elasticity, 15–19
  
- Electrical loading, 36, 64, 305, 381, 386
- Electrode interactions, 64–65, 66, 67, 201
  - analysis of 375–392
- Electrode polarity, 71, 76
- Electrode resistivity, 117, 166–167
- Electrostatic charge density, 40, 41, 69–72, 76
- Electrostatic probe, 129, 137, 369
- Elemental charge density, 84, 85, 89, 185, 358–360
- Element factor, 85
  - for gaps, 59, 88, 100, 185
- End effects, 66, 85, 88, 232
  - transverse, 100
- Energy theorem, 327
- Energy, velocity, 135
- Equation of motion, 17, 18
  - for isotropic material, 19
- Equi-ripple response, 198
- Equivalent circuit of transducer, 77, 158–159, 160
- Expander, 218, 242, 252
- Expansion of material, 148
- Expansion loss, for chirp, 242
- Extensions, of chirp, 228, 229, 231
  
- Fabrication, 12–13
  - of RAC, 257–258, 259
- Far-field region, 132, 139
- Film, **see** aluminium layer, gold layer, layer, piezoelectric film, zinc oxide
- Filter, **see** bandpass filter, bandstop filter, chirp filter, digital filter, linear filter, matched filter, minimum-shift-keyed waveforms, PSK filter, transversal filter
- Filter bank, 126, 209–211, 294
- Finite-impulse-response filter, 187, 197
- Flicker noise, 322
- Floquet's theorem, 108, 110, 363, 364
- Focussing transducer, 306
- Fold-over convolution, 303–304, 307, 309
- Fourier transforms, 325–329
  - sliding, 270, 275
- Fourier transform systems, 268, 270–278
  - applications of, 276–277
  - using diode convolver, 313
- Fraunhofer region, 132
- Frequency, **see** instantaneous frequency
- Frequency hopping, 293–294
- Frequency measurement, 14, 210, 268
- Frequency response:
  - of convolver, 309–310
  - of interdigital device, 97, 99, 101–105, 120
  - of interdigital transducer, **see** interdigital transducer
  - of linear filter, 330

- Frequency-scanning radar, 245, 247  
 Frequency-shift keying, 276  
   **see also** minimum-shift-keyed waveforms  
 Frequency synthesis, 210, 293–294  
 Fresnel distance, 139  
 Fresnel integrals, 139, 141  
 Fresnel region, 132  
 Fused quartz, **see** quartz, fused
- Gallium arsenide, 154, 288  
 Gating sidelobes, 228  
 Generalised function, 327, 328  
 Gold layer, 26, 27, 391  
 Green's function, 50–52  
   for bulk waves, 51  
   in diffraction analysis, 132  
   electrostatic, 51  
   symmetry of, 347–348  
   for surface waves, 50  
 Grooves, 10, 260–264, 267, 320  
   fabrication of, 257–258  
   mode conversion by, 397–399, 401  
 Group delay of chirp filter, 222, 231  
 Group-type transducer, 175–181  
 Guard electrodes, 66, 85
- Hamming weighting, 226, 227  
 High-frequency techniques, 155, 172–173, 399, 400  
 Hilbert transform, 78, 92, 199  
 Hooke's law, 16  
 Horn, 306, 307  
 Huygen's principle, 132  
 Hybrid junction transducer, 174
- Idler wave, 300, 312  
 Image responses, 189, 200  
 IMCON, 29, 219, 257, 265  
 Impulse model, 57  
 Impulse response, 331  
   of transducer, 9, 63, 189  
 Ingebrigtsen's approximation, 48–49  
 In-line RAC, 267, 399  
 Insertion loss, 8, 14, 102  
   and triple-transit, 8, 168–170  
 Instantaneous frequency, 220, 222  
   or linear chirp, 222  
 Integrating correlator, 317  
 Integration with semiconductors, 281, 287  
 Interactions, **see** electrode interactions  
 Interdigital transducer, 5, 6, 57–67, 75–105  
   admittance of, 77, 89–95, 98  
   analysis methods, 66–67  
   and bulk waves, 66, 93, 393–401  
   capacitance of, 77, 87, 93  
   channels in, 97  
   conductance of, 77, 91–93, 97, 390, 396  
   conversion coefficient of, 81, 164, 169  
   crossed-field model, 66, 375  
   delta-function model, 57–64, 85, 89, 100  
   and diffraction, 137, 138, 140–144, 206  
   double-electrode, 65, 89  
   dummy electrodes in, 97  
   electrode interactions in, 64, 67, 375–392  
   electrode resistivity in, 166–167  
   equivalent circuit, 77, 158–159, 160  
   focussing, 306  
   frequency response, 59, 96  
     for apodised transducer, 9, 62, 99, 100, 387–390  
   Green's function analysis, 67  
   guard electrodes in, 66, 85  
   harmonics, 59, 60, 91, 172–173  
     strengths of, 87, 93, 95  
   hybrid junction, 174  
   impulse model, 57  
   impulse response, 9, 63, 189  
   launching surface waves, 76, 81, 96, 99  
     351–353  
     with regular electrodes, 57–60, 62, 85  
   matching, 160–162  
     and loss, 162–165  
   multi-electrode, 65, 233  
     **see also** uniform transducer  
   neighbour effect in, 66  
   with parasitics, 165–168  
   with piezoelectric layer, 54–55, 287, 314  
   Q-factor, 94, 159, 162, 164  
   quasi-static analysis, 67, 75–82  
   radiation resistance of, 160–161, 168  
   receiving surface waves, 60, 78–82, 96, 98, 99  
   reciprocity for, 79, 348–351  
   reflection coefficient, 64–65, 80–82, 101, 386–387  
   with regular electrodes, 83–95, 99  
   and sampling, 187–191  
   scattering coefficients, 80–82  
   second-order effects in, 64–67  
   single-electrode, 65, 89  
   standing wave ratio, 165  
   susceptance (acoustic) 77, 78, 92  
   thinned, 200–201  
   transmission coefficient, 81  
   as transversal filter, 185–187  
   weighting of, 201–202, 209  
     **see also** apodised transducer  
   withdrawal-weighted, 66, 201–202  
   voltage standing wave ratio, 165

- see also** apodised transducer, array factor,  
chirp transducer, element factor, multi-phase  
transducer, transducer, triple-transit signal,  
unidirectional transducer, uniform transducer
- Isotropic material, 19
  - waves in, 19–29
- Kaiser window, 195–196
- L–C filter, 183, 207, 208
- Lamb waves, 28
- Lamé constants, 19
- Layer, effect on surface waves, 26, 36, 154–155
  - see also** aluminium layer, gold layer,  
piezoelectric film, zinc oxide
- Layered Rayleigh wave, 26, 219
- Leaky surface wave, 36
- Legendre functions, 355–358
- Legendre polynomials, 248, 357–358
- Linear chirp, 218, 220, 222–229
  - bandwidth of, 223
  - doppler effect, 254
  - spectrum, 223
  - weighting of, 224–229
  - see also** chirp waveform
- Linear filter, 6, 330–332
- Lithium niobate, 3, 5, 152, 153
  - with aluminium layer, 26, 147, 154
  - beam steering in, 137
  - bulk waves in, 46, 153, 395–396, 397, 401
  - diffraction in, 137, 139, 140
  - effective permittivity, 46
  - non-linear effects in, 146–147, 296, 300, 301, 316
  - propagation loss, 144
  - pseudo-surface wave in, 36, 399
  - in reflective array compressor, 257, 258, 260,  
264, 265
  - rotated orientation ( $128^\circ$ ), 153, 397
  - surface waves in, 33, 34, 46, 153
  - temperature coefficient, 148, 153
  - velocity accuracy, 140, 150–151
  - Y, Z orientation, 33, 46, 140, 152, 153
  - propagation effects in, 144, 146, 148, 150
- Lithium tantalate, 153–154, 155
- Lithography, 12–13
- Loading, **see** electrical loading, electrode  
interactions, mass loading, mechanical  
loading, stored energy, topographic effect
- Longitudinal waves, 1, 20, 30
  - in surface-wave devices, 395
- Love waves, 27, 219
- Mass loading, 36, 391
- Matched filter, 10, 332–334
  - for chirp waveform, 216, 219, 220
  - see also** chirp filter
  - in communication systems, 283–285
  - convolver as, 298–300
  - for minimum-shift-keyed waveform, 293
  - for phase-shift-keyed waveform, 286–290
  - in radar systems, 215–219
  - see also** correlation of long waveforms
- Matched pair, 219, 242, 244, 252
- Matching of transducers, 100, 160–162
- Materials, 151–155
  - see also** aluminium nitride, anisotropic  
material, berlinite, bismuth germanium  
oxide, ceramics, gallium arsenide, isotropic  
material, lithium niobate, lithium tantalate,  
lithium tetraborate, quartz, zinc oxide
- Matrix notation for tensors, 18
- Mechanical loading, 45, 375, 390–392
- Mehler-Dirichlet formula, 356
- Memory, **see** storage
- Metallisation ratio, 83, 95
- Metallised surface, 31, 32, 46
- Microscan receiver, **see** compressive receiver
- Minimal-diffraction orientations, 136–137, 153,  
154
- Minimum-phase filter, 199–200
- Minimum-shift-keyed (MSK) waveforms,  
290–293, 299
- Mirror, 123–124
- Misalignment, 135, 150, 151
- Mis-match loss, 227, 231
- Mixing of surface waves, 6, 147, 296
  - see also** acoustic convolver
- Modes, of multi-strip coupler, 107, 113, 114, 117,  
126
- Mode conversion, 397–399, 401
- Modulation theorems, 326
- Monolithic crystal filter, 4
- Multi-electrode transducer, 65
  - see also** uniform transducer
- Multi-phase transducer, 173–181
  - analysis of, 176–181
  - performance of, 176
- Multi-strip coupler, 5, 107–127,
  - beam compression, 126–127
  - bulk waves in, 118, 119, 398
  - diffraction in, 118
  - echo trap, 124
  - electrode resistance in, 117, 123, 124, 127
  - in filter bank, 126, 210–211
  - in interdigital device, 118–120, 203
  - mirror, 123–124
  - modes in, 107, 113, 114, 117, 126

- narrow-band, 124–126
- reflection coefficient, 118, 386
- in reflective array compressor, 267
- in resonator, 321
- scattering matrix, 121
- second-order effects in, 117–118
- stop bands in, 108, 114, 118, 363, 370–372
- track-changer, 124
- in unidirectional transducer, 120–123
- Near-field region, 132, 134, 139
- Neighbour effect, 66
- Noise, 331–334
- Non-destructive testing, 2
- Non-linear chirp, 218, 229–231
  - doppler effect, 254–255
  - see also** chirp waveform
- Non-linear effects, 145–147
  - in convolvers, 6, 281, 295–296, 301, 312, 313
- Normal mode theory, 49, 55
- Nyquist frequency, 188, 339
- Optical image scanning, 314
- Optical probes, 130–132, 140, 145
- Orientation of material, 30, 36
  - see also** misalignment
- Oscillator:
  - using crystal resonator, 3, 318, 321, 322
  - using surface-skimming bulk waves, 399, 400
  - using surface waves, 11, 318–323
- Packaging, 13
- Paired echos, 248
- Parallel-plate transducer, 3
- Parallel plate, waves in, 28, 29, 400–401
- Parasitic (stray) components, 100, 165–168
- Parseval's theorem, 326
- Partial waves, 22, 26, 31, 42
- Passive generation, 218, 219, 242
  - see also** expander, matched pair
- Performance of surface-wave devices, 13–14
- Periodic structure, 108, 363–374, 376–380
  - reflection coefficient, 380, 386–387
  - see also** multi-strip coupler, reflective array model
- Permittivity tensor, 17, 18, 31
  - see also** effective permittivity
- Perpendicular diffraction delay line, 219
- Perturbation theory, 37, 66, 108
- Phase plate, 243, 258, 259, 265
- Phase shift keyed (PSK) waveform, 218, 282, 286–290
  - doppler effect, 290
  - matched filter for, 11, 14, 283, 286–290, 299
  - see also** correlation of long waveforms
- Photolithography, 12–13
- Piezoelectric ceramics, 154
- Piezoelectric coupling, 31, 33
  - across gap, 52
  - constant ( $k^2$ ), 153
- Piezoelectric film, 154–155
  - see also** zinc oxide
- Piezoelectric Rayleigh wave, 33, 46
  - power of, 47–48
- Piezoelectric tensor, 18, 31
- Piezoelectricity, 3, 5, 17
- Piezoresistive effect, 287
- Plane waves:
  - in anisotropic material, 30
  - in isotropic material, 1, 19–21, 25
- Plate, **see** parallel plate
- Port, of transducer, 76
- Posts, 313
- Power of surface wave, 47–48
- Poynting vector, 135–136
- Probing, 6, 129–132
- Processing gain, 217
- Programmable devices, **see** convolver, variable devices
- Programmable PSK filter, 287–288
- Propagation effects, 129–151
  - see also** beam steering, diffraction, dispersion, non-linear effects, propagation loss, temperature effects, velocity accuracy
- Propagation loss, 129, 144–145, 151
  - in metal film, 154
- Pseudo-noise code, 283
- Pseudo-surface wave, 35, 399
- PSK filter, 11, 14, 283, 286–290
  - programmable, 287–288
- Pulse-compression radar, 10, 214–219
  - see also** chirp filter, chirp waveform
- Pure mode direction, 33, 135
- Pure waves, 30, 33
- PZT, 154, 301
- Q-factor:
  - of transducer, 94, 159, 239
  - of resonator, 3, 320, 322
- Quadrature three-phase transducer, 174
- Quartz, crystalline, 153
  - with aluminium layer, 26, 150, 154
  - bulk waves in, 393, 399, 400
  - leaky surface waves in, 36
  - non-linear effects in, 147, 296
  - propagation loss in, 144–145
  - pseudo-surface waves in, 35
  - Rayleigh waves in, 35

- in reflective array compressor, 258, 267
  - SST orientation, 153
  - ST cut, 144, 148–149, 150, 153
  - temperature coefficient, 148–149, 150, 153, 258
- Quartz, fused, 19, 24
  - with gold layer, 26, 27
  - plane waves in, 21
  - Rayleigh waves in, 24
  - see also** silicon oxide
- Quasi-longitudinal wave, 30
- Quasi-shear wave, 30
- Quasi-static approximation, 67–70, 75, 108, 109
- Radar, 14, 211, 277
  - frequency-scanning, 245, 247
  - pulse-compression, 9, 10, 214–219
  - see also** chirp filter, chirp waveform
- radiation resistance, 160–161
- Rayleigh wave:
  - in isotropic material, 21–24
  - and Lamb waves, 28
  - layered, 26, 36
  - piezoelectric, 33, 35, 36, 46
  - pure, 33
  - non-piezoelectric, 32
  - see also** leaky surface wave, lithium niobate, pseudo-surface wave, quartz
- Reciprocity, 343–353
  - Auld's relation, 343–344
  - for surface-wave transducers, 79, 348–351
- Reciprocal ripple design, 228–229, 231
- Recirculation loop, 317–318
- Reflective array, 209
  - see also** reflective array compressor, reflective array model, resonator
- Reflective array compressor (RAC), 10, 13, 14, 256–267
  - analysis, 259–264
  - bulk waves in, 264, 399
  - in compressive receiver, 275, 276, 277
  - using dot array, 267
  - fabrication, 257–258, 259
  - in-line, 267, 399
  - length weighted, 267
  - with metal reflectors, 267
  - non-synchronous scattering loss, 264
  - performance, 265–267
  - phase plate in, 258
  - second-order effects in, 261–265
  - short-circuit response, 261
  - temperature effects in, 258–259, 267
- Reflective array model, 376–380
- Reflective dot array, 209, 267
- Regular electrodes, 83, 84, 87, 89, 109, 375
  - waves in, 363–374, 375–386
- Remez exchange algorithm, 197
- Resistivity:
  - of aluminium film, 167
  - of electrodes, 117, 166–167
- Resonator:
  - crystal, 3, 4, 29
  - surface-wave, 11, 209, 319–321, 398
- Rigidity, 19
- Sagittal plane, 21
- Sampling, 187–189
  - of amplitude-modulated waveform, 191, 339–341
  - of chirp waveform, 191, 239–240, 336–337
  - non-uniform, 192, 334–337
  - synchronous, 233, 235, 336
- Sapphire, 3, 155
- Scaling theorem, 326
- Scattering coefficients:
  - of electrode, 376–377, 385, 386, 391
  - of multi-strip coupler, 115, 117, 121
  - of transducer, 80–82
- Schwartz's inequality, 333
- Seismology, 2, 25
- Semiconductor convolver, 312–316
- Semiconductor substrate, 55
  - see also** gallium arsenide, silicon
- Sezawa modes, 27
- Shape factor, 207
- Shear-horizontal (SH) waves, 25, 27, 29, 34, 399
- Shear waves, 2, 20, 21, 25, 33
  - in anisotropic materials, 30
  - in quartz, 35
  - in surface-wave devices, 395
- Shifting theorems, 326
- Short-circuit response:
  - of interdigital device, 97, 99, 102, 104, 105, 120
  - of reflective array compressor, 261
- Sidelobes, **see** time-sidelobes
- Signal processing, 6, 8
  - see also** chirp filter, compressive receiver, convolver, diode convolver, Fourier transform systems, matched filtering, pulse-compression radar, spread-spectrum communications
- Signal-to-noise ratio, 215, 217, 227, 284, 308, 318, 332–334
- Silicon, 37, 287, 313–317
- Silicon oxide, 155, 173, 313
  - see also** quartz
- Single-electrode transducer, 65, 89, 91, 95, 163, 164
  - and sampling, 191, 192



- electrode interactions in, 64–65, 389–390
- Slanted chirp transducer, 243, 398
- Sliding Fourier transform, 275
- Slowness, 133
- Slowness curve, 133
- Sonar, 277
- Space harmonics, 108, 363
- Spectrum analysis, 268–277
  - see also** filter bank
- Split-electrode transducer, **see** double-electrode transducer
- Spread-spectrum communications, 11, 14, 282–285
- ST-cut quartz, 144, 148–149, 150, 153
- Standing-wave ratio, 165
- Stationary-phase approximation, 221–222
  - limitations of, 223, 228–229, 231
- Stationary-phase point, 221
- Step function, 329
- Stiffness tensor, 16, 17, 18, 31
  - for isotropic material, 19
  - in matrix notation, 18
- Stop bands, 108, 378
  - in multi-strip coupler, 108, 114, 118
  - in regular electrodes, 370–372, 385, 386
- Storage, 314–316
- Storage convolver, 314–316
- Stored energy, 264, 320
- Straight-crested wave, 132
- Strain, 15
- Stray components, **see** parasitic components
- Stress, 16, 17
- Strip delay line, 219
- Substrate, 7
  - see also** materials
- Superposition, **see** charge superposition, linear filter
- Surface-skimming bulk waves (SSBW) 399–400
- Surface waves, 2, 21
  - in anisotropic materials, 32–35
  - in isotropic materials, 21–24, 25–27
  - technology for, 4–6
  - see also** Bleustein Gulyaev waves, leaky surface waves, Love waves, pseudo-surface waves, Rayleigh waves, Sezawa modes
- Susceptance of transducer (acoustic), 77, 78, 92
- Symbol, in communications, 283
- Synchronous sampling, 233, 235, 239, 336
- Tapped delay line, 11, 172
  - see also** PSK filter
- Tapped delay line correlator, 316
- Taylor weighting, 227
- Television, 3, 14, 207, 208, 400
- Temperature effects, 129, 147–150, 153–154
  - in bandpass filter, 206
  - in chirp filter, 250–252
  - in convolver, 303
  - in oscillators, 322–323, 399, 400, 401
  - in PSK filters, 289–290
  - reduction of, 13, 155, 218–219, 322–323, 399, 401
  - in reflective array compressor, 247, 258–259, 267
  - in two-transducer devices, 149
- Thinning, 200–201, 286, 318
- Three-phase transducer, 173–174, 176, 179
- Three-transducer scheme, 170–171
- Time-invariant device, 330
- Time scaling, 279
- Time-sidelobes, 216, 247, 248, 249
  - reduction of, 218, 224–231
- Time reversal, 279, 300
- Topographic effect, 391
- Track-changer, 124
- Transducer:
  - for bulkwaves, 3, 399–400
  - parallel-plate, 3
  - reciprocity for, 344–347, 348–351
  - for surface waves, 6
  - see also** interdigital transducer
- Transform, **see** Fourier transform, Hilbert transform
- Transmission-line effects, 256, 304, 307
- Transmission matrix:
  - of electrode, 377
  - of periodic structure, 379–380
- Transversal filter, 125, 185–187, 240
- Transverse end effect, 100
- Transverse waves, **see** shear waves
- Traps, 203
- Triple-transit signal, 8, 64, 100
  - analysis of, 102, 104, 105, 120, 168–170
  - in bandpass filter, 176, 205, 207, 208
  - in chirp filter, 242
  - and insertion loss, 168–170
  - reduction of, 170–171
- Tuning, **see** matching
- Turn-over temperature, 149, 150
- Unidirectional transducer, 170
  - multi-phase type, 173–181
  - using multi-strip coupler, 120–123
- Uniform transducer, 8, 57, 59, 89–95, 158–171
  - bandwidth of, 158–165
  - with parasitic components, 165–168
- Up-chirp waveform, 220

- Variable devices, *see* bandpass filter, chirp filter, convolver, delay line, programmable PSK filter
- Velocity, energy, 135
- Velocity of surface waves, 23, 26, 33, 35
  - accuracy of, 150–151
  - in lithium niobate, 33, 150–151
  - measurement of, 140, 151–152, 369
  - in regular electrodes, 369
  - temperature coefficient of, 148
- Voltage standing-wave ratio (VSWR), 165
- Vibration of oscillators, 322
- Waveguide, 5, 305–306
- Waveguide convolver, 305–311
- Waves, *see* acoustic waves, surface waves
- Wave vector, 20, 133
- Wedge delay lines, 219
- Weighting, of interdigital transducer, 201–202, 209
  - see also* apodised transducer, linear chirp, non-linear chirp, withdrawal weighting
- Weighting functions for chirp waveforms, 226–227
- White noise, 332
- Window functions, 193–196
- Withdrawal weighting, 66, 176, 201–202, 203
- Wrap-around delay line, 172
- Zeros, in filter responses, 183, 199
- Zinc oxide, 3, 6, 37, 55, 154
  - in bandpass filter, 208
  - in convolvers, 314, 315
  - in PSK filters, 287

ISBN 0-444-88845-4