

INDEX

A

- active antennas, 264, 277
- adapters, 271, 275–276
- ADCs. *See* analog-to-digital converters
- Add blocks
 - equalizers, 106
 - low-pass filters, 93–94
 - modeling noise, 294–295
 - plotting complex sounds, 72–77, 84
- Add Const blocks
 - amplitude modulation, 203
 - Multiply blocks versus, 84–85
 - Multiply Const blocks versus, 84–85
- aliasing, 228–233
- AM. *See* amplitude modulation; AM radio systems
- AM Demod blocks
 - AM receiver creation, 47–50, 55
 - converting AM to FM, 145
 - demodulation, 130
 - setting properties, 132–133
 - viewing demodulated signals, 131
- AM radio systems, 5–9, 37–55
 - adding radio data sources, 41–42
 - amplitude modulation, 8–9
 - converting AM to FM, 142–147
 - output, 51–54
 - receivers, 107–139
 - demodulation, 129–133
 - input RF data, 108–112
 - resampling, 133–138
 - tuning, 112–129
 - setting up the variables and entries, 38–41
 - signal processing, 42–51
 - AM Demod blocks, 47–49
 - Low Pass Filter blocks, 45–47
 - Multiply blocks, 44–45
 - Rational Resampler blocks, 49–51
 - Signal Source blocks, 42–44
 - signals, 6–8
 - tuning, 6
- amplifiers, 81
 - active antennas, 264
 - DC offset, 248
 - low-noise amplifiers, 277
 - traditional radios versus SDRs, 222–223
- amplitude, 8
- amplitude modulation (AM), 8–9, 197–206.
 - See also* AM radio systems
 - avoiding overmodulation, 204–206
 - choosing between modulation schemes, 219–220
 - flawed modulators, 198
 - negative baseband values, 200–204
 - phase reversal, 201–202
 - waveform, 197
- analog-to-digital converters (ADCs), 12–15, 19, 224–234
 - aliasing, 228–233
 - arbitrary waveforms, 14–15
 - filtering, 233–234
 - sinusoids, 13–14
 - square waves, 12–13
- anechoic chambers, 177
- ANT500, xxi, 259–260, 275, 287
 - experimenting with, 265–269
 - setting up, 184–186
- antennas, 256–269, 275
 - baluns, 276
 - characteristics of
 - bandwidth, 257
 - directivity, 258
 - frequency, 257
 - gain, 257, 287–288
 - impedance, 258–259
 - size, 257
 - connecting, 184–186, 253
 - electric and magnetic fields, 256

- antennas (*continued*)
 - electromagnetic waves, 256–257
 - experimenting with, 265–269
 - GPS, 277
 - location of, 287
 - mitigating noise, 270
 - polarization, 265
 - selection of, 287
 - types of, 259–264, 277
 - active, 264, 277
 - dipole, 260–262
 - loop, 262–263
 - telescoping, 259–260
 - whip, 259
 - yagi, 263–264
- application-specific integrated circuits (ASICs), xix
- attenuation, 83–84, 86–90, 156, 205–206
 - band-reject filters, 104
 - RF attenuators, 277
- Audio Sink blocks
 - AM receiver creation, 51, 53
 - applying gain to signals, 80–81
 - bandwidth, 173
 - generating tones, 61
 - plotting complex sounds, 74–75
 - signal recovery, 289–290
 - visualizing tones, 61–62
- audio underrun, 240
- B**
- baluns, 276
- band-limited signals, 226, 233
- Band Pass Filter blocks, 103
- band-pass filters, 102–104
- Band Reject Filter blocks, 104
- band-reject (notch) filters, 104
- bandwidth, 144, 168–176, 235–240
 - antennas, 257
 - channel width versus, 171–172
 - identifying limits, 235–236
 - overflow, 236–240
 - passband, 169–170
 - sampling rate and, 235
- baseband, 194–196
 - negative values, 200–204
- baseband (BB) gain, 241–243, 247
- bias tees, 277
- bladeRFs, 190
- blocks, 23–33. *See also* flowgraphs; *names of specific blocks*
 - adding to flowgraphs, 26–28
 - changing properties, 31–33
 - connecting, 29
 - copying, 40–41
 - data types, 39
 - deleting connections, 34
 - finding, 24, 26–27
 - moving around, 28
 - port colors, 49–50, 109
 - sinks, 26
 - sources, 25–26
- BNC connectors, 273
- C**
- capture window, 226–227
- carrier signal, 5. *See also*
 - amplitude modulation
 - zero-frequency carriers, 208–210
- channel width, 171
 - bandwidth versus, 171–172
 - cutoff frequency versus, 150–151
- classic radios, xvii–xviii, 222–223
- clipping, 245–246
- clock input/output ports, 253
- coaxial connectors, 273
- complex mixing, 148
- complex sinusoidal multiplication, 148, 249–250
- Complex to Mag blocks, 198–199
- computers
 - connecting SDR hardware to, 186
 - interface speed, 269
 - noise, 269–271
 - speed of, 269
 - storage capacity, 269
- connectors, 184–186, 253, 271–274
 - BNC, 273
 - coaxial, 273
 - male and female, 271
 - MCX, 271–272
 - RCA, 272
 - RP-SMA, 274
 - SMA, 271
 - SO-239, 273–274

- Constant Source blocks, 26
 - adding to flowgraphs, 27–28
 - changing properties, 31–32
 - connecting blocks, 29
- cosine waves, 198, 224–225
- cutoff frequency, 92, 96
 - audio pass property, 132
 - band-pass filters and, 102–103
 - band-reject filters and, 104
 - baseband, 194
 - channel width versus, 150–151
 - converting AM to FM, 144–145

D

- DACs. *See* digital-to-analog converters
- data types, 39
- decibels (dB)
 - gain, 85–90
 - real-world radio systems, 90
- decibels relative to an isotropic antenna (dBi), 257
- decimation, 134–136, 228
- deemphasis, 281
- demodulation, 5, 9, 129–133. *See also* modulation
 - AM Demod block properties, 132–133
 - viewing demodulated signals, 131–132
- digital modulation, 217–219
- digital-to-analog converters (DACs), 16, 19, 242
- dipole antennas, 260–262, 275
- direct current (DC)
 - offset, 247–251
 - quantity, 248
 - spike, 247, 249, 251
- directivity of antennas, 258
- discrete Fourier transforms (DFTs), 68
- duty cycle, 286

E

- electromagnetic spectrum, 164–165
- electromagnetic waves, 164–168
 - antennas, 256–257
 - frequency bands, 166
 - polarization, 265

- propagation, 165
- wavelength versus frequency, 167–168

- equalizers, 105–106
- Ettus USRPs, 189–190

F

- fast Fourier transforms (FFTs), 68–80.
 - See also* frequency plots;
 - time plots
 - band-pass filters, 103–104
 - bandwidth, 173–176
 - DC offset, 247
 - decibels, 86–87
 - frequency shifting, 117–118
 - input RF data, 109–112
 - low-pass filters, 91–96
 - noise, 177–178
 - plotting
 - complex sounds, 72–77
 - real-world sounds, 77–80
 - simple tones, 68–72
 - waterfall plots, 211
 - tuning, 112–113, 127–128
- Federal Communications Commission (FCC), 172, 274, 286–287
- ferrite chokes, 270, 277
- fidelity, 175
- field-programmable gate arrays (FPGAs), xix
- File Source blocks, 26
 - AM receiver creation, 42, 46, 52, 55
 - converting AM to FM, 143
 - DC offset, 251
 - FM receiver tuning, 147, 158
 - frequency shifting, 114
 - input RF data, 108–110
 - noise, 177
- filters and filtering, 46, 91–105, 118–126
 - after interpolation, 284–285
 - analog-to-digital conversion, 233–234
 - band-pass, 102–104
 - band-reject, 104–105
 - high-pass, 97–102
 - low-pass, 91–97, 119–122
- finite impulse response (FIR) filters, 148–151
- Float to Complex blocks, 198–199, 203

- flowgraphs, 21, 23–25. *See also* blocks; *names of specific blocks and flowgraph goals*
- blocks
 - adding to flowgraphs, 26–28
 - changing properties of, 31–33
 - connecting, 29
 - sink, 26
 - source, 25–26
 - changing sample rate, 51–52
 - errors in, 30, 47
 - execution window, 53–54
 - input and output, 33–36
 - mathematical functions, 33–36
 - saving and running, 29–31
- FM radio systems, 141–159
 - converting AM to FM, 142–147
 - improving receivers, 147–159
 - automatic variable updating, 152–154
 - effective tuning, 147–152
 - finding other signals, 158–159
 - volume control, 154–157
 - transmitters, 280–286
 - audio source, 280–281
 - filtering after interpolation, 284–285
 - signal modulation, 281
 - signal upconversion, 281–283
- Fourier, Joseph, 68
- Fourier transforms, 67–68. *See also* fast Fourier transforms
- fractional resampling, 138
- frequency, 60. *See also* frequency plots
 - aliasing, 229–230
 - antennas, 257, 266–268
 - audible spectrum
 - generating tones, 60–61
 - varying frequency, 64–67
 - visualizing tones, 62–64
 - band-pass filters, 103–104
 - bandwidth, 173–176
 - bands, 166, 219
 - baseband, 196
 - complex sounds, 72–77
 - DC offset, 247
 - decibels, 86–89
 - demodulation, 132
 - FM transmitters, 283, 285, 291, 293, 296
 - HackRF SDR operation, 188
 - high-pass filters, 98–100, 102
 - input RF data, 109–112
 - low-pass filters, 92–96, 121–125
 - modulation
 - adjusting modulator sensitivity, 212–213
 - waterfall plots, 211
 - zero-frequency carriers, 209
 - noise, 178–179
 - oversampling, 237
 - real-world sounds, 77–80
 - simple tones, 68–72
 - tuning, 127–128, 159
 - visualizing signals in frequency domain, 67–80
 - complex sounds, 72–77
 - real-world sounds, 77–80
 - simple tones, 68–72
- Frequency Mod blocks, 207–209, 211, 214
- frequency modulation (FM), 142, 206–214. *See also* FM radio systems
 - adjusting modulator sensitivity, 211–214
 - building modulators, 280–286
 - audio source, 280–281
 - filtering after interpolation, 284–285
 - signal modulation, 281
 - signal upconversion, 281–283
 - choosing between modulation schemes, 219–220
 - waterfall plots, 210–211
 - zero-frequency carriers, 208–210
- frequency offset, 249
- frequency plots, 67–72. *See also* fast Fourier transforms; frequency
- frequency shifting, 113–118
- frequency translation, 148
- Frequency Xlating FFT Filter blocks, 147
- Frequency Xlating FIR Filter blocks
 - automatic variable updating, 152–154

- bandwidth, 169
 - DC offset, 250
 - hardware-enabled flowgraphs, 183
 - improving tuning effectiveness, 147–151
 - modeling noise, 294–295
 - oversampling, 238
 - signal recovery, 289–290
 - full duplex, 252
 - full-scale input, 244
- G**
- gain, 80, 240–246
 - antennas, 257, 287–288
 - attenuation, 83
 - decibels, 85–90
 - effect on signals, 80–85, 243–246
 - setting, 243
 - stages of, 241–242
 - GNU Radio, 21–36. *See also names of specific flowgraph goals*
 - blocks, 23–26
 - adding to flowgraphs, 26–28
 - changing properties, 31–33
 - connecting, 29
 - deleting connections, 34
 - sinks, 26
 - sources, 25–26
 - flowgraphs, 21, 23
 - adding blocks to, 26–28
 - connecting blocks, 29
 - creating, 24, 26
 - errors in, 30
 - example of, 25
 - mathematical functions, 33–36
 - saving and running, 29–31
 - GNU Radio Companion GUI, 23–26
 - installing, 22–23
 - simulations, xx
 - GPS antennas, 277
- H**
- HackRFs, xxi, 246
 - antennas
 - active, 264
 - attaching, 184–186
 - experimenting with, 265–269
 - impedance, 259
 - transmit gain, 287–288
 - connectors, 271
 - gain stages, 241–242, 246–247
 - operating, 187–188
 - resetting, 187
 - setting up, 184–187
 - connecting to
 - computer, 186
 - lights, 186–187
 - specifications, 251–253
 - superheterodyne structure, 223
 - upconverters, 276
 - updating firmware, 187
 - half duplex, 252
 - hardware, 181–191, 246. *See also*
 - antennas; HackRFs
 - bandwidth and sample rates, 235–240
 - identifying bandwidth limits, 235–236
 - overflow, 236–240
 - bladeRFs, 190
 - creating hardware-enabled
 - flowgraphs, 182–184
 - DC offset, 247–251
 - Ettus USRPs, 189–190
 - gain, 240–246
 - IQ sampling, 224–234
 - analog-to-digital conversion, 226–234
 - IQ signals, 224–225
 - LimeSDRs, 190
 - modulation, 193–220
 - amplitude, 197–206
 - baseband signals, 194–196
 - choosing between schemes, 219–220
 - digital, 217–219
 - frequency, 206–214
 - phase, 215–217
 - peripherals, 255–278
 - antennas, 256–269
 - computers, 269
 - connectors, 271–274
 - noise mitigation, 270–271
 - toolkit, 274–278

hardware (*continued*)

- PlutoSDRs, 190
- requirements for activities in
 - book, xxi
- specifications
 - antenna connector, 253
 - clock, 253
 - full duplex or half duplex, 252
 - interface, 253
 - number of channels, 252
 - operating frequency, 251–252
 - resolution, 252
 - RF output power, 253
 - RX gain, 252
 - sampling rate, 252
 - system power, 253
 - TX gain, 252
- hardware-defined radios, SDRs
 - compared to, xvii–xviii
- harmonics, 291–293, 296
 - distortion, 291
- hertz (Hz), 60
- heterodyning, 223
- high-frequency (HF) signals, 166
- High Pass Filter blocks, 97
- high-pass filters, 97–102

I

- impedance, 258–259
- input bandwidth, 110–111
- instrumentation blocks, 26
- intermediate frequency (IF), 222–223
 - gain, 241–242, 247, 287–288
- International Telecommunications Union
 - (ITU), 164
- interpolation, 137–138, 283–284
- IQ (quadrature) sampling, 224–234
 - analog-to-digital conversion,
 - 226–234
 - aliasing, 228–233
 - filtering, 233–234
 - IQ signals, 224–225

K

- Keep 1 in N blocks
 - aliasing, 228–229
 - decimation, 134–137
- kilohertz (kHz), 6

L

- leading and lagging, 216–217
- licensed spectrum, 286
- LimeSDRs, xxi, 190
- Linux, installing GNU Radio on, 22
- loop antennas, 262–263, 275
- low-noise amplifiers (LNAs), 277
- low-noise block downconverters
 - (LNBs), 277
- Low Pass Filter blocks, 93–94
 - AM receivers, 45–47, 55, 119–120
 - bandwidth, 173
 - converting AM to FM, 144–145
- low-pass filters, 91–97, 119–125

M

- macOS, installing GNU Radio on, 22–23
- MCX connectors, 271–272
- medium-frequency (MF) signals, 166
- microwave frequencies, 165
- millimeter wave frequencies, 165
- modulation, 5. *See also* demodulation
 - amplitude, 8–9, 197–206
 - avoiding overmodulation,
 - 204–206
 - flawed modulators, 198
 - negative baseband values,
 - 200–204
 - phase reversal, 201–202
 - waveform, 197
 - baseband signals, 194–196
 - choosing between schemes,
 - 219–220
 - digital, 217–219
 - frequency, 142, 206–214
 - adjusting modulator
 - sensitivity, 211–214
 - building modulators, 280–286
 - waterfall plots, 210–211
 - zero-frequency carriers,
 - 208–210
 - phase, 215–217
- monopole (whip) antennas, 259
- Multiply blocks
 - Add Const blocks versus, 84–85
 - amplitude modulation, 198–199
 - AM receivers, 44–45

- filtering, 119
- FM transmitters, 281–282
- frequency shifting, 115–116
- signal processing, 44–45
- Multiply Const blocks
 - Add Const blocks versus, 84–85
 - gain, 242
 - applying to signals, 80–85
 - transmit, 287
 - input and output, 33–35
 - overmodulation, 206
 - phase modulation, 215–216
 - volume control, 155–156

N

- narrow-band FM (NBFM), 280
- noise, 129, 176–179
 - mitigating, 270–271
 - modeling for testing purposes, 294–296
 - signal-to-noise ratio, 178–179
 - sources of, 269
 - viewing, 177–178
- Noise Source blocks, 178, 294–295
- notch (band-reject) filters, 104
- number of channels, 252
- Nyquist frequency, 226–233, 235
- Nyquist-Shannon sampling theorem, 226

O

- offset error, 248–249
- onion analogy, xx, 54, 74, 163
- online resources
 - Factoria Labs, 23
 - GNU Radio website, 22
 - project and input data files, xxiii, 41, 78
- on-off keying (OOK), 219
- operating frequency, 251–253
- Options blocks, 38, 114, 280
- overflow, 236–240
- overmodulation, 204–206

P

- passband
 - bandwidth, 91, 169–170
 - equalizers, 105
 - filters, 100–103

- periodic phenomena, 60
- peripherals, 255–278
 - antennas
 - characteristics of, 257–259
 - experimenting with, 265–269
 - polarization, 265
 - types of, 259–264
 - computers, 269
 - connectors, 271–274
 - noise mitigation, 270–271
 - toolkit, 274–278
 - adapters, 271, 275–276
 - antennas, 275
 - baluns, 276
 - upconverters, 276
- Phase Mod blocks, 215–217
- phase modulation (PM), 215–217, 219–220
- phase reversal, 201–202, 204–205
- PlutoSDRs, xxi, 190
- polarization, 265
- power sources, mitigating noise
 - from, 270
- preemphasis, 281
- propagation, 165

Q

- QT GUI Entry blocks
 - adjusting frequency modulator sensitivity, 211
 - AM receiver creation, 38–41, 43, 53–54
 - filtering, 119–120, 122
 - band-pass, 103
 - high-pass, 101
 - low-pass, 94–95
 - FM transmitters, 280
 - frequency shifting, 115–116
 - modeling noise, 294
 - oversampling, 236
 - signal recovery, 289–290
- QT GUI Frequency Sink blocks
 - bandwidth, 173, 235
 - baseband, 194–195
 - decibels, 85–86
 - frequency shifting, 114–116
 - gain, 243
 - hardware-enabled flowgraphs, 183

- QT GUI Frequency (*continued*)
 - input RF data, 108–109, 111
 - noise, 177
 - oversampling, 238
 - plotting complex sounds, 74–77
 - plotting simple tones, 68–69
 - tuning, 126–127, 158
 - viewing modulated and demodulated signals, 131
- QT GUI Range blocks
 - aliasing, 228–229
 - applying gain to signals, 81
 - bandwidth, 173
 - decibels, 86
 - overmodulation, 204
 - varying frequency of tones, 65
 - volume control, 154–157
- QT GUI Time Sink blocks
 - adding to flowgraphs, 28
 - amplitude modulation, 203–204
 - applying gain to signals, 80–82
 - connecting to other blocks, 29
 - decibels, 85
 - decimation, 134–135
 - filtering, 119
 - input and output, 34
 - phase modulation, 215
 - plotting complex sounds, 74–75
 - visualizing tones, 62–63
- QT GUI Waterfall Sink blocks, 210
- quadrature sampling. *See* IQ sampling

R

- radio frequency (RF)
 - attenuators, 277
 - gain, 241–243, 246–247, 287–288
 - limiters, 277–278
 - output power, 253
- radio systems, 3–10. *See also* AM radio systems; FM radio systems
 - simple
 - modulation, 5
 - receivers, 3–10
 - signals, 4–5
 - transmitters, 5–6, 19
 - traditional versus SDRs, xvii–xviii, 222–223

- Rational Resampler blocks
 - AM receivers, 49–51, 55, 138
 - automatic variable updating, 153–154
 - converting AM to FM, 146
 - FM transmitters, 281–285
 - signal recovery, 289–290
 - volume control, 155–156
- RCA connectors, 272
- receivers
 - AM, 37–55, 107–139
 - demodulation, 129–133
 - input RF data, 108–112
 - resampling, 133–138
 - tuning, 112–129
 - digital signal processing, 11–20
 - FM, 141–159
 - automatic variable updating, 152–154
 - effective tuning, 147–152
 - finding other signals, 158–159
 - volume control, 154–157
 - GNU Radio, 21–36
 - signal processing, 59–106
 - simple systems, 3–10, 19
- resampling, 133–138
 - AM receivers, 138
 - decimation, 134–136
 - interpolation, 137–138
- resolution, 252
- RP-SMA connectors, 274
- RX gain, 252

S

- sampling, 11–16
 - analog-to-digital conversion, 12–15
 - digital-to-analog conversion, 16
 - IQ, 226–234
 - period, 16
 - rates, 16–18, 51–52, 235–240
 - bandwidth and, 235
 - hardware specifications, 252
 - overflow, 236–240
 - undersampling, 17–18
- sawtooth waves, 125
- SDRs. *See* software-defined radios
- shielded cables, 270

- signal physics, 163–179
 - bandwidth, 168–176
 - channel width versus, 171–172
 - passband, 169–170
 - electromagnetic waves, 164–168
 - electromagnetic spectrum, 164–165
 - frequency bands, 166
 - propagation, 165
 - wavelength versus frequency, 167–168
 - noise, 176–179
- signal processing, 11–20, 59–106
 - AM radio systems, 42–51
 - equalizers, 105–106
 - filters, 91–105
 - band-pass, 102–104
 - band-reject, 104–105
 - high-pass, 97–102
 - low-pass, 91–97
 - frequency, 60–80
 - audible spectrum, 60–67
 - visualizing signals in the frequency domain, 67–80
 - gain, 80–90
 - applying to signals, 80–85
 - decibels, 85–90
 - sampling, 11–18
 - analog-to-digital conversion, 12–15
 - digital-to-analog conversion, 16
 - sample rate, 16–18
 - simple SDR systems, 18–19
- Signal Source blocks, 26
 - AM receivers, 42–44
 - amplitude modulation, 198
 - negative baseband values, 200
 - applying gain to signals, 80–81
 - converting AM to FM, 144
 - FM modulators, 282
 - frequency modulation, 207–208
 - frequency shifting, 115
 - generating tones, 61
 - plotting complex sounds, 72–77
 - plotting real-world sounds, 78
 - varying frequency, 65
 - visualizing tones, 61–62
- signals, 4. *See also* signal physics; signal processing
 - AM radio systems, 6–9
 - carrier, 5, 7
 - information communicated by, 4–5
 - simple radio systems, 4–5
 - square wave, 12–13
- signal-to-noise ratio (SNR), 178–179, 219, 243–245, 270
- sinks, 26. *See also names of specific sink blocks*
- sinusoids (sine waves), 7
 - analog-to-digital conversion, 13–14
 - phase reversal, 202
 - sample rates, 16–18
 - visualizing tones, 62–63
- SMA connectors, 271, 275
- SO-239 connectors, 273–274
- Soapy HackRF Sink blocks, 282, 287
- Soapy HackRF Source blocks
 - gain, 241, 247, 288
 - hardware-enabled flowgraphs, 183–184
 - oversampling, 238
- software-defined matter, xix
- software-defined radios
 - developmental history of, xix
 - hardware
 - function of, 221–253
 - interfacing with, 181–191
 - modulation, 193–220
 - peripherals, 255–278
 - transmitting signals, 279–296
 - hardware-defined radios
 - compared to, xvii–xviii
 - onion analogy, xx, 54, 74, 163
 - prototyping RF components of new products, xix–xx
- receivers
 - AM, 37–55, 107–139
 - FM radio systems, 141–159
 - GNU Radio, 21–36
 - signal processing, 11–20, 59–106
 - simple systems, 3–10, 19
 - signal physics, 163–179
 - simple systems, 18–19
 - simulated, xx

- software-defined radios (*continued*)
 - transmitters, xviii–xix
 - simple systems, 19
 - transmitting signals, 279–296
 - use cases, xviii–xix
- sources, 25–26. *See also names of specific source blocks*
- square waves, 12–13
- stopband, 91, 100–102, 105
- subsonic frequencies, 60
- superheterodyne (superhet) radios, 222–223
- system power, 253

T

- telescoping antennas, 259–260
- terahertz (THz), 164
- Throttle blocks
 - adding to flowgraphs, 28
 - connecting to other blocks, 29
 - decimation, 134–135
 - frequency shifting, 112
 - function of, 136–137
 - noise, 177
- time plots, 68–80. *See also fast Fourier transforms*
 - band-pass filters, 103–104
 - complex sounds, 72–77
 - decimation, 135
 - demodulation, 129
 - frequency modulation
 - adjusting modulator sensitivity, 212–213
 - waterfall plots, 211
 - zero-frequency carriers, 209
- gain, 81–84, 244–246
- high-pass filters, 98–102
- low-pass filters, 95–96, 121–125
- real-world sounds, 77–80
- simple tones, 68–72

- toolkit, 274–278
- adapters, 271, 275–276
- antennas, 275
- baluns, 276
- upconverters, 276
- traditional radios, xvii–xviii
- versus hardware, 222–223
- transition width, 100–102

- transmitters, xviii–xix, 279–296
 - FM, 280–286
 - audio source, 280–281
 - filtering after interpolation, 284–285
 - signal modulation, 281
 - signal upconversion, 281–283
 - logistics, 286–288
 - legal issues, 286
 - practical issues, 286–288
 - simple systems, 5–6, 19
 - testing, 288–289
 - modeling noise, 294–296
 - running flowgraph, 290–293
 - signal recovery, 289–290
- tuning, 6, 112–129
 - AM receivers, 127–129
 - filtering, 118–126
 - FM radio systems
 - finding other signals, 158–159
 - improving effectiveness, 147–152
 - frequency shifting, 113–118
 - real-world frequencies, 126–127
- TX gain, 252

U

- UHD:USRP Source blocks, 189–190
- ultra-high-frequency (UHF) signals, 166
- ultrasonic frequencies, 60
- underflow, 239–240, 269
- unlicensed spectrum, 286
- upconverters, 276, 281–283

V

- Variable blocks, 38, 52, 54, 150, 177
- very high-frequency (VHF) signals, 166
- virtual machines (VMs)
 - choppy audio, 52
 - installing GNU Radio on, 23
- volume control, 154–157

W

- waterfall plots, 210–211
- wavelength, 167
 - distance, 168
 - frequency versus, 167–168

Wav File Source blocks, 78, 173, 280
WBFM Receive blocks
 automatic variable updating,
 153–154
 baseband, 194–195
 converting AM to FM, 145–146
 signal recovery, 289–292
WBFM Transmit blocks, 281
whip (monopole) antennas, 259

wideband FM (WBFM), 280
Windows, installing GNU Radio on,
 22–23

Y

yagi antennas, 263–264

Z

zero-frequency carriers, 208–210