

Index

a

ABCD matrix 190
 Abel transform 69
 Abel inversion 92
 absorption coefficient 130–132
 active diagnostics 65–115, *See also*
 Polarimetry; Reflectometry; Scattering;
 Interferometry
 Airy function 89
 all-digital phase measurement 301–303
 all-digital phase meter 301, 302
 Altair–Appleton–Hartree-equation 31, 41,
 147
 alternative decorrelation 271–272
 – single-sightline correlation experiments
 272
 analog output, phase measurements with
 299–300
 antenna arrays
 – array factor 219
 – element factor 219
 antennas 208–221
 – antenna arrays 217–221
 – – frequency-scanned array 220
 – – phased array 218
 – antenna gain 209
 – antenna temperature 211–212
 – antenna theorem 210, 258
 – basic definitions 208–211
 – characterizing parameters 209
 – conical horn 214–215
 – directivity 210
 – Gaussian beam excitation 217–219
 – pyramidal horn 212–213
 – receiving 208
 – transmitting 208
 anti-Hermitian part of dielectric
 tensor 23

antireflection coating 198
 aspect ratio 5

b

B_0 -field varying along sightline 135–137
 backward waves 219
 backward-wave oscillator (BWO) 203–205,
 334
 band-pass filter 292
 – general definitions 293–294
 – metallic meshes 298–300
 – in overmoded waveguide 295–297
 bandwidth influence on sensitivity 259–260
 beam radius 56
 beam waist 56
 Bessel functions 172, 174
 bistatic arrangement 334
 bi-refringence
 – circular 38
 – linear 39
 bolometer 223–225
 – composite bolometer 223
 – hot electron bolometer 225–226
 Boltzmann equation 25
 Bragg-back-scattering 99
 break-even condition 9
 bremsstrahlung 117–122
 Brillouin angle 178
 Budden parameter 146
 burning plasma experiment (BPX) 375

c

cascaded systems, noise temperature of
 250–251
 chain parameters 281
 characteristic impedance 152–153
 characteristic impedance of free space
 162

- circular waveguides 170–176
 - fields in 171
 - loss in 175–176
 - circulator 287
 - coaxial transmission line 161–163
 - characteristic properties 162
 - losses in 162–163
 - coherent detectors 221, 237
 - coherent Thomson-scattering (CTS) 106, 108–109, 373–375
 - cold-plasma dispersion relations 34–42
 - finite-temperature correction to 42–48
 - nonmagnetized plasma 34
 - cold-plasma limit 29–32, 390
 - collision frequency 33
 - components and subsystems 275–313, *See also* Network-analysis measuring techniques
 - composite bolometer 223
 - Compton effect 105
 - confocal parameters 188
 - conical horn 214–215
 - constant fraction discriminator 342
 - control loop components 308–309
 - correlation radiometry 264–272
 - cross-correlation function 265–267
 - intensity fluctuations 264–266
 - and coherence 266–267
 - corrugated circular waveguides 182–185
 - fields of 183–185
 - corrugated waveguide 182–183
 - Cotton–Mouton polarimeter 75, 327, 330–322
 - common generalized description 77–83
 - Cotton–Mouton effect 75, 326–327
 - coupling coefficient for fundamental Gaussian beams 194–196
 - cross correlation 267
 - accuracy of measurements 270–271
 - function 267–268
 - crossed-waveguide construction 233
 - curvature parameter 234
 - curved mirrors 191–193
 - cyclotron emission imaging (ECEI) 347
 - cyclotron harmonic waves 145
- d**
- 1 dB compression point 305
 - Debye length 20
 - degenerate mode 174
 - density fluctuations
 - influence, in reflectometry 95–100
 - role 108
 - density gradient length 87
 - deuterium 3
 - detection 221–236, *See also* Bolometer; Diode direct detector; Heterodyne detection
 - coherent detectors 221
 - incoherent detectors 221
 - noise-equivalent power (NEP) 226
 - optimization 221–222
 - linearity 224
 - noise level 221
 - sensitivity 221
 - stability 224
 - temporal resolution 224
 - voltage or current responsivity 221
 - Schottky diode 227–229
 - deuterium–tritium (DT) fusion reaction 3
 - device under test (DUT) 288
 - dielectric tensor from kinetic theory 25
 - digital prescalars 310
 - digital-to-analog convertor (DAC) 301–302
 - diode direct detector 231–233
 - diode mixer 239–241
 - directional coupler 281–283
 - directivity 210
 - dispersion interferometer 323
 - dispersion relation of the mode 22
 - Doppler broadening 140
 - Doppler reflectometry 346–348
 - Doppler shift 102–103
 - dot matrix Schottky diode 230
 - down-shifted frequency 123
 - DT reaction 2
 - dynamic range of a component 304
- e**
- Echelette grating 356
 - effective ion charge 119
 - eigenmodes 165
 - eikonal phase 49
 - electron Bernstein wave emission 143–149
 - detection 370–373
 - electron Bernstein waves 144–146
 - mode conversion 146–149
 - O–X–B mode conversion 143
 - electron cyclotron emission (ECE), radiometry of 349–370
 - calibration 370
 - general requirements 350–354
 - heterodyne radiometers 357–362
 - imaging (ECEI) 362–363
 - system parameters 363–366
 - electron cyclotron emission (ECE) 122–143
 - absorption coefficient 130–132
 - B₀-field varying along sightline 135–137

- electric field and spectrum, single electron 123–126
 - electron cyclotron absorption (ECA) measurement 142–143
 - electron motion in a static field 122–123
 - emission profile 132–135
 - optical depth of most relevant modes 137–140
 - perpendicular observation, characteristic modes 126–128
 - spectrum, electron ensemble 128–130
 - visibility depth and localization 140–142
 - electron cyclotron frequency 27
 - electron cyclotron resonance heating (ECHR) 10, 290
 - electron gyration radius 122
 - electron motion in a static field 122–123
 - elliptical waveguide 373
 - emission profile 132–135
 - emissivity 128
 - energy confinement time 8
 - even Matthieu functions 373
 - extraordinary mode (X-mode) 39
- f**
- Faraday effect 71–75, 82
 - Faraday polarimeter 329–330
 - far-infrared (FIR) wavelength 319
 - fast X-wave 146
 - finite Larmor radius (FLR) approximation 42–44
 - finite-size probing beam 54–58
 - finite-temperature correction to cold-plasma dielectric tensor 42–48
 - first-order active loop filter 311
 - first-order product 307
 - fluctuation measurements 345–346
 - flux surface 4
 - form factor 104
 - Fourier–Bessel expansion 124, 244
 - Fourier spectroscopy 352
 - Fellgett advantage 355
 - Jaquinot advantage 355
 - free–free radiation 117
 - frequency-selective filters 290–299
 - band-pass filter 290
 - high-pass filter 290
 - low-pass filter 290
 - frequency stability 308–312
 - control loop components 308–309
 - first-order active loop filter 311
 - phase margin 312
 - theoretical concept 310–312
 - frequency-scanned antenna array 220
 - frequency-selective surfaces (FSS) 299
 - fringes 299
 - full width at half maximum (FWHM) 90, 93, 341
 - fundamental dispersion relation of waves in plasmas 22
 - fundamental mode 57
 - fundamental TE₁₀-wave 167–170
 - fusion research 1–17
 - magnetic plasma confinement 4–10
 - proton-proton-chain (pp-chain) 2
 - reaction scheme 1–3
- g**
- gain compression 304–305
 - Gauss-Hermite polynomials 57
 - Gaussian beam 185–196
 - coupling coefficient for 194–196
 - description 55–58
 - excitation of 215–217
 - lenses and curved mirrors 191–193
 - quasi-optical system components 191
 - solution of approximate wave equation 185–186
 - telescope 188
 - transformation of 186–191
 - truncation of 193–194
 - Gaussian beam parameter 190
 - Gaussian beam telescope 188
 - Gouy phase 56
 - grating spectrometer 356–357
 - grid constant 300
 - group velocity 35
 - guided waves 151–199. *See also* circular waveguides; coaxial transmission line; corrugated circular waveguides; Gaussian beams; multimode waveguides; transmission lines; transverse electric (TE) waves; transverse magnetic (TM) waves
 - Gunn diode 231
 - Gunn oscillator 203–205
 - donation layers 206
 - I/V-characteristic of Gunn diode 206
 - limited space-charge accumulation (LSA) mode 206
 - quenched-domain mode 206
 - typical housing with screwable heat sink 206
- h**
- half-wave window 197–198
 - Hanbury-Brown and Twiss experiment 269
 - Hankel function 120
 - harmonic mixing 239

- helical field lines 4, 7
 - Helmholtz equation 52, 89
 - Hermitian part of dielectric tensor 23
 - heterodyne detection 236–246
 - diode mixer 239–241
 - mixer construction 245–246
 - square law mixer 237–238
 - two-port mixer 241–244
 - heterodyne radiometers 357–362
 - heterodyne receiver, noise temperature of 253–255
 - high-density polyethylene (HDPE) 192
 - high-pass filter 292
 - hot electron bolometer 225–226
 - hot–cold technique 367
 - hot-plasma dielectric tensor 27
 - hybrid mode 185–194
 - HE₁₁ characteristics 185
 - hybrid-factor 184
- i**
- IQ detection 305
 - image frequency 242
 - image port 240
 - image sideband 240
 - imaging reflectometry 348
 - IMPATT oscillator 207–208, 231
 - incoherent detectors 221
 - incoherent scattering 104–106
 - inhomogeneous plasma 48–54
 - inhomogeneous plasma 48
 - in-phase and quadrature signals 304
 - input matching network 245
 - integrated data analysis (IDA) 11
 - intensity interferometer 269–270
 - interferometer 315–326
 - dispersion interferometer 323
 - frequency stability 320–321
 - 2ω -interferometer 323
 - Mach–Zehnder heterodyne interferometer 319–320
 - Mach–Zehnder interferometer 318–319
 - multichannel interferometer 324–326
 - path length variations 322–323
 - swept frequency interferometer 324
 - two-color-interferometer 322
 - wavelength 316–317
 - interferometry 65–70
 - multiple chords 69–70
 - single-chord interferometry 68
 - intermodulation 305–308
 - first-order product 307
 - products of order $|m| + |n|$ 308
 - third-order intercept point 307
 - International Thermonuclear Experimental Reactor (ITER) 7
 - ion cyclotron resonance heating (ICRH) 10
 - ionogram 333
 - isolator 285
- j**
- Joint European Torus (JET) 10
- k**
- Kirchhoff's law 131
- l**
- L-wave 37
 - Larmor formula 103
 - Larmor radius 27
 - Lawson criterion 8
 - lenses 191–193
 - limited space-charge accumulation (LSA) mode 206
 - line-integrated density 68
 - Lithium 3
 - impedance transformation 156
 - localization of reflecting layer 93–94
 - Lorentz force 4, 123
 - lossy transmission line, waves on 151–153
 - low density polyethylene (LDPE) 192
 - lower sideband (LSB) 359
 - low-pass filter 292
- m**
- Mach–Zehnder heterodyne interferometer 319–320
 - magnetic axis 4
 - magnetic plasma
 - confinement 4–10
 - physics issues of 7–9
 - magnetized plasma
 - parallel propagation 37–38
 - perpendicular propagation 39–41
 - magnification 187
 - Martin–Puplett polarizing interferometer 354–356
 - grating spectrometer 357–359
 - Maxwell averaged Gaunt factor 120
 - Maxwell–Boltzmann velocity 128
 - metallic meshes, in band-pass filter 298–300
 - Michelson interferometer 352–354
 - microwave diagnostics 15–16
 - microwave imaging reflectometry (MIR) 350
 - millimeter-wave range, PLL circuits in 309–310
 - millimeter-waves in plasmas 19–62, *See also* cold-plasma dispersion relations

- basic equations 20–23
 - derivation within fluid description 32–34
 - dispersion relation of the mode 22
 - fundamental dispersion relation of waves in plasmas 22
 - millisecond time scale 12
 - minimum detectable temperature 263–264
 - minimum detectable blackbody temperature 263
 - mixer construction 245–246
 - input matching network 245
 - mixer noise temperature 251–253
 - mode coupling 179
 - modulation factor 338
 - modulation techniques 327–329
 - Scheme 1 327–328
 - Scheme 2 328–329
 - Scheme 3 329
 - monolithic microwave-integrated circuits (MMICs) 205
 - mono-mode propagation, TE_{11} 180–191
 - monostatic arrangement 336
 - Müller matrix 327–329
 - multichannel interferometer 324–326
 - multifrequency systems 332–338
 - multimode waveguides 176–181
 - mono-mode propagation, TE_{11} 180–191
 - multimode propagation 178–179
 - number of modes propagating 176–178
 - multiple chord interferometry 69–70
 - multiple chords, imaging 61–62
 - multiplier chain 206–207
 - mutual coherence function 267
- n**
- network-analysis measurement 290–312
 - errors in 290
 - reflection measurement 287–288
 - substitution measurement 288–289
 - transmission measurement 286–287
 - using noise sources 289–290
 - neutral beam injection (NBI) 10
 - noise-equivalent power (NEP) 226, 260–261
 - coherent detection 261–263
 - incoherent detection 260–261
 - noise figure 249–250
 - noise sources, measurements using 289–290
 - noise temperature 247–249
 - of cascaded systems 250–251
 - of heterodyne receiver 253–255
 - measurement of 255
 - mixer noise temperature 251–253
 - nonmagnetized plasma 34
 - nonreciprocal devices 283–286
 - normal dispersion 35
 - Nyquist relation 246
- o**
- odd Mathieu functions 346
 - off-axis system 192
 - O-mode 42
 - ohmic heating 10
 - Onsager relation 23
 - optical depth 60, 133, 137
 - optical depth, in electron cyclotron emission 137–140
 - ordinary mode (O-mode) 39
 - overmoded circular waveguides, TE_{11} mode in 180–181
 - overmoded waveguide, band-pass filter in 295–297
 - O–X–B mode conversion 143, 146
- p**
- passive diagnostics 117–149, *See also* Electron Bernstein wave emission; Electron cyclotron emission
 - path length variations 322–323
 - phase change at cutoff in reflectometry 75–92
 - phase margin 312
 - phase measurement 299–304
 - all-digital phase measurement 300–303
 - all-digital phase meter 301
 - with analog output 299–300
 - input signals of 302
 - output signals of 302
 - by software 303–304
 - phase memory concept 50
 - phase runaway 346
 - phased antenna array 218
 - phase-locked loop (PLL) 308, 309, 311, 320
 - in millimeter-wave range 309–310
 - phase velocity 35
 - photoconductor detectors 221
 - physics issues of magnetic confinement 7–9
 - pitch angle 4
 - Planck’s law 249
 - plasma anisotropy 21
 - plasma diagnostic 11–16, *See also* Microwave diagnostics
 - active diagnostics 15
 - generic arrangements 12–15
 - passive diagnostics 15

- plasma dielectric tensor 23–25
 - general properties 23–25
 - wave propagation geometry 24
 - plasma dispersion function 28
 - plasma emitting and absorbing 60–61
 - plasma frequency 27
 - plasma heating 10
 - heating schemes 10
 - plasma pressure 8
 - Poincare sphere 79
 - polarimeter 326–332
 - modulation techniques 327–329
 - polarization state, evolution 326–327
 - polarimetry 70–83
 - Cotton-Mouton effect 75
 - Faraday effect 71–75
 - polarization filters 300
 - polarization rotator 181–182
 - polarization-selective filters 290–299
 - polarizing Martin–Puplett interferometer 300
 - polytetrafluoroethylene (PTFE) 192
 - power coupling coefficient 194
 - power range 309
 - power wave amplitudes 153
 - Poynting vector 124
 - profile reconstruction 92–93
 - proton-proton-chain (pp-chain) 2
 - pulse radar technique 339–342
 - pyramidal horn 212–213
- q**
- Q-factor 9
 - quenched-domain mode 206
- r**
- R-wave 37
 - radiation generation and detection 201–250
 - radiation transfer 58–62
 - multiple chords, imaging 61–62
 - plasma emitting and absorbing 60–61
 - transparent plasma 58–60
 - radio detection and ranging (RADAR) 15
 - ray refractive index 60, 132
 - ray tracing 53–54
 - Rayleigh–Jeans limit 132, 222, 262
 - Rayleigh length 56
 - ray refraction 51–53
 - realized millimeter-wave diagnostic systems architecture 315–378, *See also* interferometer; polarimeter; reflectometer; Radiometry of electron cyclotron emission; Detection of electron Bernstein waves; Coherent Thomson scattering receiver noise temperature 262
 - reciprocal device 277
 - rectangular waveguides 163–170
 - rectangular waveguides, attenuation in 166–167
 - recurrence formula 297
 - redundancy 10
 - reflection measurement 287–288
 - reflectometer 332–348
 - fluctuation measurements 345–346
 - heterodyne version of 358
 - multifrequency systems 332–338
 - ultrashort pulse radar 342–343
 - reflectometry 83–100
 - density fluctuations influence 95–100
 - localization of reflecting layer 93–94
 - phase change at cutoff 89–92
 - profile reconstruction 92–93
 - relativistic corrections 95–96
 - time delay measurement 86–87
 - refraction 51–53
 - refractive index 22
 - relativistic corrections 46–48
 - relativistic incoherent scattering spectrum 106–107
 - return loss 156
 - rotational transform 4
- s**
- safety factor 6
 - saturation 304–305
 - scaling law 9
 - scattering 100–115
 - coherent scattering 108–109
 - density fluctuations role 108
 - Doppler shift 102–103
 - electron and ion feature 110–113
 - form factor 104
 - incoherent scattering 104–106
 - parameters 275–277
 - relativistic incoherent scattering spectrum 106–107
 - single-particle Thomson scattering 101–102
 - Thomson scattering 100
 - Schottky detector noise 233–236
 - Schottky diode 227–229
 - dot matrix Schottky diode 228
 - frequency multiplier 229–231
 - Schott–Trubnikov formula 126, 127

sensitivity limits 256–264
 – bandwidth influence 259–260
 – minimum detectable temperature 263–264
 – noise-equivalent power 260–261
 – – coherent detection 263–265
 – – incoherent detection 260–261
 – shot noise term 254–257
 – thermal radiation term 259–259
 shear 4
 shot noise 256–260
 signal linearity 304–308
 – gain compression 304–305
 – intermodulation 305–308
 signal sources 201–207, *See also* Antennas;
 Correlation radiometry; Detection
 – backward-wave oscillator (BWO) 201–203
 – multiplier chain 206–207
 – solid-state oscillators 203–206, *See also*
individual entry
 single-chord interferometry 68
 single-disk window 196–197
 single-particle Thomson scattering 101–102
 single sideband (SSB) 360
 single sideband modulation (SSBM)
 techniques 320
 slightly oblique propagation 41–42
 slow X-wave 146
 ‘smearing out’ effect 353
 Snell’s law 59
 software, phase determination by 303–304
 solid-state oscillators 203–206, *See also*
 Gunn oscillator; IMPATT oscillator
 spatial dispersion 28
 square law mixer 237–238
 stellarator 6–7
 Stix geometry 24
 Stokes equation 89
 Stokes vector 78, 79, 326
 stub 157
 substitution measurement 288–289
 subsystems 275–313, *See also* Two-port
 characterization
 susceptibility 109
 superconductor–insulator–superconductor
 (SIS) 239
 surface currents 160–161
 sustainable fusion power 3
 swept frequency interferometer 324
 swept single-frequency system 333–337
 – bistatic arrangement 334
 – monostatic arrangement 334
 system impedance 276
 system noise temperature 255

t

tangential sensitivity 236
 terminated transmission line 153–157
 thermal noise 246–255, 264
 – noise temperature 247–249, *See also*
individual entry
 thermal radiation term 258–259
 thin window 198
 third-order intercept point 307
 Thomson scattering 100
 – coherent Thomson scattering (CTS)
 106
 – single-particle Thomson scattering
 101–102
 time-of-flight (TOF) measuring system 342
 tokamak 5–6
 toroidal field coils 7
 torus 4–5
 total power receiver 357
 transmission lines 151–161
 – classification of 157–159
 – properties 151–161
 – surface currents 160–161
 – terminated transmission line 153–157
 – two-conductor transmission line 152
 – waves on a lossy transmission line
 151–153
 transmission measurement 286–287
 transparent plasma 58–60
 transverse electric (TE) waves 159, 164–165,
 173–175
 – fundamental TE₁₀-wave 167–170
 – mono-mode propagation, TE₁₁ 180–191
 – TE₁₁ mode in overmoded circular
 waveguides 180–181
 transverse electromagnetic (TEM) wave 40
 transverse magnetic (TM)-waves 40, 166,
 172–173
 triple product 8
 tritium 3
 two-color-interferometer 322
 two-port characterization 275–286
 – directional coupler 281–283
 – nonreciprocal devices 283–286
 – reflection 278–279
 – scattering parameters 275–277
 – transmission 278–281
 two-port mixer 241–244
 two-tone test 306

u

ultrashort pulse radar 342–343
 – distance calibration 344–345
 – spurious reflections 344–345

upper hybrid frequency 39
upper sideband (USB) 358, 361

v

vacuum windows 196–199
– antireflection coating 198, *See also individual entry*
– half-wave window 198
– mounted inside a circular waveguide 197
– single-disk window 196–197
– thin window 198
van Cittert-Zernike theorem 268–269
varactor multipliers 233
video bandwidth 235
visibility depth and localization, in electron cyclotron emission 140
Vlasov equation 25, 32, 46
Voigt effect 39
voltage-controlled oscillator (VCO) 311
voltage standing wave ratio (VSWR) 156

w

warm plasma approximation 44–46
wave heating 10
wave noise 266
waveguide band-stop filter 294–295
wavelength 316–317
waveguide attenuation 393–395
wave-packet 340
weakly relativistic model 46
Wentzel–Kramers–Brioullin (WKB) approximation 49–51
wire diameter 300

x

X-B mode conversion 143, 146
X-mode 42

y

Y-factor method 255, 349