

Index

- 2D Helmholtz equation, 130
- 2D Kirchhoff integral approach, 139
- 2D ray tracing, 177
- 3D Kirchhoff integral approach, 148
- 3D ray tracing, 181
- Abel integral equation, 215
- absorbing boundary condition, 28, 153
- absorption, 189
- absorption constant, 190
- acoustic cut-off frequency, 166
- Airy function, 130, 199, 241
 - asymptotic expansion, 242
 - integral representation, 242
 - zeros, 242
- amplitude fading, 192
- amplitude modulation (AM), 4
- anisotropic media, 23, 80, 87
- antenna
 - efficiency, 4
 - reactance, 5
 - reciprocity, 41
- Appleton–Hartree formula, 26, 82, 172
- atmospheric noise, 193
- attenuation, 21
- attenuation constant, 21, 111, 220
- auroral oval, 164
- auroral scatter, 96
- back scatter, 12
- backward difference, 247
- bandwidth, 4
- Bessel equation, 242
- Bessel function, 242
 - asymptotic expansion, 243
 - integral representation, 243
- Booker scattering formula, 96
- Born approximation, 98
- Bouger’s law, 79
- boundary conditions, 27
- Breit and Tuve theorem, 169
- Brewster angle, 33
- Brunt–Vaisala frequency, 166
- Bullington method, 57
- canonical solutions, 61, 130
- carrier signal, 4
- caustic surface, 75, 202
- cellular radio, 7
- central difference, 247
- channel impulse response function, 68, 119, 232
- channel scattering function, 232
- channel simulation, 118
- Chapman layer, 161
- charge density, 16
- Charpit equations, 71, 82, 83
- circular polarisation, 20, 225
- clutter, 94
- coherence bandwidth, 231
- coherence
 - in the frequency domain, 113
 - in the spatial domain, 111
- collision loss, 189
- compensation theorem, 44, 213
- complementary variational principles, 89
- conductivity, 16
- conformal transformation, 130
- conjugate point, 254
- cononical solutions, 278
- continuity equation, 16, 18
- Crank–Nicolson scheme, 138
- current density, 16
- cut-off frequency, 131, 196
- cylindrical polar coordinates, 237
- D layer, 161
- Debye formula, 204
- delay spread, 68
- deviative loss, 190
- dielectric constant, 16
- diffraction, 10, 55
 - over a cylinder, 63
 - over a screen, 61
 - over a wedge, 62
- diffraction loss, 57
- dipole, 5, 35
- dipole antenna, 4
- directivity, 4, 35
- discrete Fourier transform (DFT), 260

- dispersion, 21
- displacement invariant, 142, 261
- disturbed ionosphere, 166
- divergence theorem, 237
- domain truncation, 137, 143, 153
- Doppler shift, 9, 226
- Doppler spread, 68, 98, 235
- ducting, 12

- E layer, 161
- Earth flattening, 133, 148, 197
- Earth's curvature, 145
- Earth's magnetic field, 163
- effective antenna area, 36, 50
- effective antenna length, 5, 42
- effective permittivity, 20
- effective relative surface impedance, 216
- eikonal, 70
- Einstein summation convention, 254
- electric flux density, 16
- electric intensity, 16
- electromagnetic waves, 2
- elevated duct, 207
- elliptical polarization, 20
- equatorial anomaly, 164
- equivalent vertical frequency, 169
- Euler Method, 249
- Euler–Lagrange equations, 174, 254
- evanescence, 131, 196
- evaporation duct, 205
- external noise, 192
- extinction theorem, 46, 122
- extremely low frequencies (ELF), 273

- F layer, 161
- F1 layer, 161
- fading, 68, 191
- Faraday rotation, 87, 191, 225
- fast Fourier transform (FFT), 142, 261
- Fermat's principle, 53, 87, 224, 258
- finite difference (FD) methods, 134, 136
- finite difference time domain (FDTD) methods, 151
- finite element (FE) methods, 72, 90, 134, 256
- flutter, 68
- forward difference, 247
- forward scatter, 12
- Fourier integral theorem, 259
- Fourier transform, 259
- Fraunhofer zone, 34
- free space, 50
- frequency modulation (FM), 4
- Fresnel clearance, 57
- Fresnel integrals, 57, 66, 67, 218
- Friis equation, 6, 9, 50, 52
- full wave solutions, 194

- gain, 4, 36
- galactic noise, 193
- generalized parabolic equation, 136
- generalized power spectral density (GPSD), 230
- generalized power spectrum, 119
- generalized Snell's law, 79
- geometric optics (GO), 70
- geometric series, 245
- geometric theory of diffraction, 60
- GPS navigation, 224
- gravity waves, 166
- grazing angle, 142
- ground loss, 59
- ground reflection loss, 191
- ground, effect on a source, 48
- group delay, 22, 85, 224
- group distance, 22, 71
- group refractive index, 85

- Hankel function, 243
 - asymptotic expansion, 245
 - integral representation, 245
 - zeros, 245
- Hanning window, 142
- Haselgrove equations, 83, 182
- height gain function, 216
- Helmholtz equation, 98, 110, 130
- high frequencies (HF), 273
- high ray, 178
- homogeneous function, 256
- horizontally stratified medium, 78
- Huygens' principle, 10, 40

- impedance boundary condition, 27, 214
- impedance of the propagation medium, 18
- infinite uniform scatters, 278
- integral equation for surface wave, 215
- integral equation propagator, 139
- internal noise, 192
- ionosonde, 167
- ionospheric layers, 161
- ionospheric propagation, 12, 72
- irregular media, 94
- irregular terrain, 145, 209

- Jacobi equation, 77
- Jacobi test, 254, 256

- Kirchhoff integral approximation, 139
- Kirchhoff scattering theory, 126
- knife edge diffraction, 61
- Kp index, 164

- lapse rate, 204
- Legendre test, 254
- linear model of ionosphere, 200
- linear polarization, 20

- Lorentz force, 16
- Lorentz reciprocity theorem, 39
- loss resistance, 5
- low frequencies (LF), 273
- low ray, 178
- M units, 205
- magnetic flux density, 16
- magnetic intensity, 16
- magneto-ionic effects, 80, 189
- manmade noise, 193
- Martyn’s theorem, 169
 - for attenuation, 191
- maximum usable frequency (MUF), 171
- Maxwell’s equations, 15
- MCF. *See* mutual coherence function
- medium frequencies (MF), 273
- micrometeors, 220
- midpoint rule, 247
- mid-latitude trough, 164
- mobile communications, 68
- mode expansion, 131
- modified Friis equation, 52
- modified refractive index, 134, 145
- modulation, 3
- multipath fading, 68, 192
- mutual coherence function (MCF), 102, 228
 - for plane wave, 109
 - for spherical wave, 109
- mutual impedance between antennas, 42, 56, 59, 95
- Nelder–Mead method, 182, 263
- Newton’s method, 248
- Newton–Raphson method, 90, 248, 263
- noise, 6, 192
- noise directionality, 193
- non-deviative loss, 190
- normal incidence, 28
- numerical differentiation, 247
- numerical integration, 247
- numerical solution of ODEs, 249
- O ray, 175
- oblique incidence, 30
- oblique ionogram, 171
- ocean spectrum, 126
- Ohm’s law, 16
- over the horizon propagation, 60, 204
- parabolic equation, 135
 - for average field, 110
 - for MCF, 111
- parabolic ionosphere, 73
- parameter invariant functional, 256
- paraxial approximation, 135
 - in ionosphere, 196
- peak plasma frequency, 161
- perfectly electrically conducting (PEC), 27
- perfectly magnetically conducting (PMC), 27
- perfectly matched layer (PML), 153
- permeability, 16
- permittivity, 16
- phase delay, 22, 72, 85, 224
- phase distance, 22
- phase modulation (PM), 4
- phase refractive index, 85
- phase screen approximation, 114
- physical optics, 126
- plane harmonic wave, 19
- plane to spherical wave transform, 63, 101, 109
- plane wave, 17, 23
- plane wave Rytov approximation, 101
- Poeverlein method, 175
- point-to-point ray tracing, 182
- Poisson summation formula, 245, 279
- polar coordinate ray tracing, 77
- polarization, 19
 - efficiency, 50
 - fading, 192
 - vector, 76
- power impulse response function, 118
- Poynting vector, 16, 18, 26, 75, 84
- principal radii of curvature, 54
- propagation constant, 19, 220
- propagation losses, 187
- propagation
 - through forest, 216
 - through rain, 219
 - through water, 219
- pseudo Brewster angle, 33
- pseudo reciprocity, 42
- pulse propagation, 153
- quadratic structure function, 231
- quadrature rules, 247
- quasi parabolic layer, 79
- quasi vertical propagation, 170
- radar, 8
 - cross section, 9
 - equation, 8, 9
- radiating source, 33
- radiation resistance, 5
- radiation zone, 34
- rain attenuation, 219
- ray homing, 180
- ray path deviations, 77
- Rayleigh criterion, 121
- Rayleigh roughness parameter, 121, 207
- Rayleigh scattering, 95, 219
- Rayleigh–Ritz method, 89, 256
- Rayleigh–Taylor instability, 227
- rays, 71

- reciprocity, 38, 94
- recovery effect, 213
- recursive FFT algorithm, 261
- reflection, 51
 - by curved surfaces, 54
 - by ground, 53
 - coefficient, 32, 142, 147
 - coefficient for irregular terrain, 147
- refraction, 11
- refractive index, 71
- refractive index surface, 173
- relative impedance, 32
- relative surface impedance, 47, 215
- rooftop diffraction, 65
- rough sea, 207
- rough surface boundary condition, 28
- rough surface scattering, 121
- Runge–Kutta (RK) method, 71, 249
- Runge–Kutta–Fehlberg (RKF) method, 71, 251
- Rytov approximation, 98, 99, 101, 107, 109, 140
- scale height, 160
- scatter propagation, 95
- scattering, 12
 - cross section, 126
 - by dielectric anomaly, 95
- Schumann resonance, 196
- Schwarz–Christoffel transformation, 131
- scintillation, 13, 227
- sea spectrum, 125
- secant law, 169
- secant method, 248
- second-order Rytov approximation, 107
- shadow region, 55
- shooting and bouncing rays, 126
- shooting method, 180
- short dipole, 36
- signal to interference ratio (SIR), 8
- signal to noise ratio (SNR), 7, 194
- Simpson’s rule, 248
- skip zone, 74, 178
- sky wave, 159
- small scale irregularity, 226
- Snell’s law, 11, 72, 78, 79, 170
- solar wind, 163
- solution of ODEs, 249
- Sommerfeld formula, 215
- spectrum of the irregularity, 96
- specular direction, 121
- specular reflection, 121
- spherical wave Rytov approximation, 102
- spherically stratified medium, 79
- Spitze*, 176
- split step algorithm, 140
- spreading loss, 6, 188
- stability, 138, 154
 - of FD methods, 137
 - of FDTD methods, 154
- stationary functional, 253
- stationary phase, 240
- Stokes equation, 241
- stratified media, 265
- structure function, 104
- sunspot cycle, 161
- sunspot number, 161
- surface impedance, 27, 147
- surface roughness, 207
- surface waves, 58, 211
 - for undulating ground, 216
- temperature inversion, 204
- three-layer medium, 270
- time harmonic field, 18
- time harmonic Poynting vector, 19
- topography, effect of, 209
- total electron content (TEC), 224
- total loss, 68, 191
- transionospheric propagation, 222
- transmission curve, 171
- transmission through a screen, 29
- transverse electric (TE), 31, 276, 277
- transverse magnetic (TM), 31, 276–278
- trapezoidal rule, 247
- traveling ionospheric disturbance (TID), 166
- trigonometric identities, 239
- trigonometric series, 245
- tropospheric scatter, 96
- two-layer medium, 219, 265
- ultra high frequencies (UHF), 273
- urban propagation, 64
- variational calculus, 253
- variational principle, 88
- vector effective antenna length, 35
- vector Helmholtz equation, 129
- vector operators, 236
- vectors, 236
- vertical ionogram, 167
- vertical propagation, 167
- very high frequencies (VHF), 273
- very low frequencies (VLF), 273
- wave equation, 17
- wavefronts
 - distortion by a curved surface, 54
 - principal radii of curvature, 188
- waveguide model of ionosphere, 194
- waves, 1
- WBMOD, 230
- weakly anisotropic medium, 86
- WKB solution for the ionosphere, 202