

# Index

3-dB width, 167  
 9-dB per delta rule, 55  
  
 acoustic tube models, 185  
 admittance matrix, 525  
 Ampère's law, 1  
 anisotropic materials, 5  
 anisotropic media, 131  
 antennas  
     aperture efficiency, 609  
     beam efficiency, 620  
     beam solid angle, 605  
     beamwidth, 602  
     bit-error rate, 627  
     center-loaded, 862  
     circular loop, 655  
     communicating, 615  
     coupled, 905  
     data rate limits, 627  
     directivity, 602  
     dish, 749  
     dish antennas, 609  
     dual-reflector, 766  
     effective area, 607  
     effective length, 613  
     EIRP, 603  
     equivalent circuits, 611  
     free-space loss, 616  
     Friis formula, 615  
     gain, 602  
     gain-beamwidth relationship, 605, 611  
     geosynchronous satellite, 629  
     ground effects, 779  
     half-wave dipole, 645  
     Hertzian dipole, 639  
     horns, 730  
     lens, 769  
     linear, 637  
     linear wire, 578  
     link budget, 631  
     load mismatch, 614  
     loop, 653  
     microstrip, 743  
     minimum-scattering, 613  
     monopole, 646  
     mutual impedance, 916  
     noise temperature, 617

normalized gain, 604  
 open-ended waveguides, 726  
 parabolic reflectors, 749  
 polarization mismatch, 614  
 power density, 602  
 radar equation, 632  
 radiation efficiency factor, 603  
 radiation resistance, 642  
 radiation vector, 639  
 receiving, 601, 862  
 reflector, 749  
 resonant, 643  
 rhombic, 650  
 satellite links, 629  
 secant antenna gain, 633  
 self impedance, 916  
 small dipoles, 641  
 square loop, 657  
 standing-wave, 641  
 transmitting, 601  
 traveling wave, 648  
 vee, 650  
 Yagi-Uda, 934  
 antireflection coatings, 169, 185, 187  
     at oblique incidence, 329  
 aperture antennas, 726  
     aperture-field method, 754  
     current-distribution method, 754  
     directivity of waveguide apertures, 729  
     dual-reflector, 766  
     horn design, 740  
     horn directivity, 737  
     horn radiation fields, 732  
     horn radiation patterns, 734  
     horns, 730  
     lens, 769  
     microstrip, 743  
     open-ended waveguides, 726  
     parabolic reflector beamwidth, 751  
     parabolic reflector gain, 751  
     parabolic reflectors, 749  
     reflector radiation patterns, 757  
 aperture efficiency, 609, 672  
 aperture-field method for reflector antennas, 754  
 apertures  
     3-dB angles, 675  
     aperture efficiency, 672

circular, 675  
 diffraction theory, 678  
 directivity of, 671  
 effective area of, 671  
 extinction theorem, 682  
 field equivalence principle, 661  
 Fourier optics, 711  
 Franz diffraction formulas, 681  
 Fresnel diffraction, 685, 711  
 geometrical theory of diffraction, 697  
 Huygens source, 669  
 Huygens-Fresnel principle, 661  
 Kirchhoff diffraction formulas, 680  
 knife-edge diffraction, 689  
 Kottler's formulas, 666, 681  
 lenses, 719  
 plane wave spectrum, 706  
 Poisson's spot, 715  
 radiation fields from, 666  
 radiation from, 661  
 radiation vectors of, 667  
 Rayleigh-Sommerfeld theory, 703  
 rectangular, 673  
 Sommerfeld's solution, 697  
 Stratton-Chu diffraction formulas, 680  
 uniform, 673  
 vector diffraction for, 684  
 apparent depth, 253  
 Appleton-Hartree equations, 150  
 array design methods, 802  
     and FIR filters, 807  
     binomial, 825  
     Blass matrix, 852  
     Butler beams, 851  
     continuous line sources, 817  
     continuous to discrete, 819  
     Dolph-Chebyshev, 826  
     DSP analogies, 807  
     endfire DuHamel, 837  
     Fourier series with windowing, 807  
     frequency-sampling, 814  
     multibeam, 850  
     narrow-beam, low-sidelobe, 821  
     prolate array, 843  
     Riblet method, 831  
     sampled current sources, 818  
     Schelkunoff's zero-placement, 805  
     secant array, 816  
     sector beam, 808  
     spatial sampling theorem, 818  
     Taylor line source, 845  
     Taylor n-bar distribution, 845  
     Taylor's one-parameter, 839  
     Villeneuve, 849  
     Woodward-Lawson, 812, 819  
         zero mapping, 819  
 array factor, 773  
 array pattern multiplication, 773  
 array processing, 785  
 array space factor, 773  
 arrays, 771  
     array factor, 773  
     array processing, 785  
     beamwidth, 797  
     beamwidth of uniform array, 791  
     coupled two-element, 922  
     directivity, 793  
     discrete-space Fourier transform, 785  
     DSP analogies, 785  
     grating lobes, 787  
     ground effects, 779  
     interferometry, 787  
     one-dimensional, 783  
     optimum directivity, 794  
     parallel dipoles, 925  
     parasitic, 931  
     pattern multiplication, 773  
     prolate matrix, 794  
     rectangular window, 790  
     sidelobes of uniform array, 792  
     space factor, 773  
     spatial z-transform, 785  
     steering and scanning, 794  
     translational phase shift, 771  
     uniform, 789  
     very large array, 788  
     very long base line, 788  
     visible region, 785  
     Yagi-Uda, 934  
 atmospheric refraction, 288  
 attenuation constant, 55  
 attenuation in waveguides, 367, 379  
 attenuator noise temperature, 622  
 available gain circles, 557  
 available power gain, 541  
  
 Babinet principle, 715  
 BAC-CAB rule, 31  
 backward recursion, *see* layer recursions  
 backward waves, 38  
 balanced stubs, 505  
 bandwidth  
     in waveguides, 376  
     noise, 617  
     of dielectric mirrors, 196  
 beam efficiency, 620  
 beam solid angle, 605  
 beamwidth, 602  
 biaxial media, 132  
 bilinear transformation, 216  
 binomial arrays, 825  
 birefringent plasmas, 34  
 birefringence  
     circular, 131  
     linear, 131  
 birefringent media, 131

Brewster and critical angles, 349  
 Brewster angle in, 350  
 critical angle of incidence in, 349  
 giant birefringent optics, 354, 355, 359  
 maximum angle of refraction in, 349  
 multilayer structures, 354  
 reflection and refraction, 345  
 bite-error rate (BER), 627  
 Blass matrix, 852  
 Bloch wavenumber, 194  
 Boltzmann constant, 617  
 Bouguer's law, 290  
 boundary conditions, 7  
   for transverse fields, 246  
   matching matrix, 246  
 BPSK modulation, 627  
 Brewster angle, 258  
   for birefringent media, 350  
   for lossy media, 260  
   in birefringent media, 349  
   in negative-index media, 296  
 broadband matching, 225  
 Butler beams, 851  
 cartesian coordinates, 366, 593  
 causality, 84  
   relativistic, 84  
 cavity resonators, 384  
 characteristic impedance, 4, 44  
 charge  
   conservation, 10  
   density, 1  
   relaxation time, 11  
 charge flux, 9  
 charge form factor, 593  
 charge relaxation, 22  
 Chebyshev transformer, 479  
 Chebyshev transformers, 225  
 chiral media, 131, 134  
 chiral media, dichroic, 139  
 chirp radar, 112  
 chirping, 102  
 circular apertures, 675  
 circular loop antennas, 655  
 coaxial cables, 408  
 collision time, 17  
 communicating antennas, 615  
 complementary error function, 627  
 complex refractive index, 54  
 complex waves, 64, 260  
 conductivity model, 20  
 conductors in magnetic fields, 33  
 conjugate matching, 476  
 constitutive relations, 3  
   in anisotropic dielectrics, 5  
   in chiral media, 134  
   in dispersive materials, 5  
   in gyroelectric media, 137

in gyromagnetic media, 137  
 in inhomogeneous dielectrics, 5  
 in linear isotropic dielectrics, 4  
 in nonlinear dielectrics, 5  
 in simple dielectrics, 4  
 in uniaxial and biaxial media, 132  
   in vacuum, 3  
 continuous line sources, 817  
   Taylor's ideal line, 821  
   Taylor's one-parameter, 821  
 coordinate systems, 958  
   cartesian, 366, 593  
   cylindrical, 366, 593  
   spherical, 593  
 cosine integrals, 960  
 coupled antennas, 905  
 coupled mode theory, 467  
   fiber Bragg gratings, 469  
 coupled transmission lines, 456  
 coupled two-element arrays, 922  
 critical angle of incidence, 250  
   for birefringent media, 349  
 crosstalk in transmission lines, 462  
 current-distribution method for reflectors, 754  
 currents on linear antennas, 855  
 cutoff wavenumber and frequency, 364  
 cylindrical coordinates, 366, 593  
 data rate limits, 627  
 delta-gap generator, 858  
 density  
   current, 1  
   electric flux, 1  
   Lorentz force, 3  
   magnetic flux, 1  
   momentum, 13, 33  
   polarization, 8  
   surface charge, 7  
   surface current, 7  
   volume charge, 1  
 dichroism, linear and circular, 138  
 dielectric constant, 4  
 dielectric mirrors, 192  
   bandwidth of, 196  
   Fabry-Perot resonators, 203  
   multiband, 201  
   narrow-band transmission filters, 203  
   omnidirectional, 198  
   shortpass/longpass filters, 202  
 dielectric model, 17  
 dielectric polarization, 4  
 dielectric slab, 162, 306  
   half-wave, 165  
   quarter-wave, 165  
   reflectionless, 165  
 dielectric waveguides, 386  
 diffraction integrals, 960  
 diffraction theory, 678

diffuse reflection and transmission  
   Kubelka-Munk model of, 472  
 dipole moment density, 4  
 dipole radiation, 658  
 directive gain, 602  
 directivity, 602  
 directivity of apertures, 671  
 discretization of continuous line sources, 817  
 dish antennas, 609, 749  
 dispersion  
   anomalous, 19  
   intermodal, 6  
   material, 6  
   normal, 19  
   waveguide, 6  
 dispersion coefficient, 99  
 dispersion compensation, 103  
 dispersive materials, 5  
 displacement current, 1  
 Dolph-Chebyshev arrays, 826  
 Dolph-Chebyshev-Riblet arrays, 831  
 doppler ambiguity, 119  
 Doppler effect, 66  
 Doppler radar, 180  
 Doppler shift, 177, 180  
 double-stub tuner, 507  
 Drude model, 21  
 DSFT, discrete-space Fourier transform, 785  
 DTFT, discrete-time Fourier transform, 785  
 dual-reflector antennas, 766  
 duality transformation, 663  
 dynamic predictive deconvolution, 185  
 effective area of an antenna, 607  
 effective area of apertures, 671  
 effective length of an antenna, 613  
 effective noise temperature, 563, 621  
 efficiency factor, 603  
 EIRP, effective isotropic radiated power, 603  
 electric and magnetic dipoles, 580  
 electric field, 1  
 electric flux density, 1  
 electromagnetic frequency bands, 950  
 elliptic functions, 873  
 elliptic integrals, 873  
 endfire DuHamel arrays, 837  
 energy conservation, 12  
 energy density, 12, 14, 25, 45  
 energy flux, 10, 12, 45, 601  
 energy velocity, 29, 40  
 equivalent noise temperature, 623  
 error function, 627  
 evanescent waves, 251  
   penetration depth for, 251  
 Ewald-Oseen extinction theorem, 585  
 exponential integrals, 960  
 extinction theorem, 585, 682  
 Fabry-Perot interferometer, 203, 308  
 far-field approximation, 590  
 Faraday rotation, 131, 138  
 Faraday's law of induction, 1  
 Fermat's principle of least time, 281  
 fiber Bragg gratings, 185, 203, 469  
   quarter-wave phase-shifted gratings, 203  
 fiber, single mode, 100  
 fiber, standard, 100  
 field equivalence principle, 661  
 field intensities, 1  
 fields of dipoles, 580  
 fields of wire antennas, 578  
 fingerprint identification, 257  
 flux  
   charge, 9  
   definition of, 9  
   energy, 10, 12  
   momentum, 10  
   Poynting vector, 12  
 flux densities, 1  
 forward recursion, *see* layer recursions  
 forward waves, 38  
 Fourier optics, 711  
 Fourier series method with windowing, 807  
 Franz diffraction formulas, 681  
 Fraunhofer region, 592  
 free-space loss, 616  
 frequency bands, 950  
 frequency-sampling array design, 814  
 Fresnel coefficients, 246, 247  
 Fresnel diffraction, 685, 711  
 Fresnel drag, 179  
 Fresnel integrals, 960  
 Fresnel region, 592  
 Fresnel rhomb, 254  
 Fresnel zones, 692  
 Friis formula, 615  
 frill generator, 858  
 front delay, 84  
 front velocity, 84  
 frustrated total internal reflection, 308  
 gain, 602  
 gain-beamwidth relationship, 605, 611  
 Galerkin weighting, 878  
 gamma-ray bands, 951  
 gauge transformation, 572  
 Gauss's laws, 1  
 geometrical optics, 278  
 geometrical theory of diffraction, 697  
 geosynchronous satellite, 606  
 giant birefringent optics, 139, 354, 355, 359  
   mirrors, 355, 356  
   reflective polarizers, 358  
 glass prisms, 252  
 Goos-Hänchen shift, 255  
 graded-index optical fibers, 293

grating lobes, 787  
 gratings, 469  
 Green's function, 860  
 Green's function for Helmholtz equation, 576  
 Green's functions, 955  
 Green's identities, 31  
 ground effects between antennas, 779  
 ground-penetrating radar, 80  
 group delay, 84  
 group index, 99  
 group refractive index, 30  
 group velocity, 29, 30, 82, 84, 94  
   in birefringent media, 142  
   in waveguides, 377  
   slow, fast, and negative, 105  
   superluminal, 85, 105  
 group velocity dispersion, 97  
 gyroelectric media, 131  
 gyromagnetic media, 131, 137, 148  
 gyrotropic media, 137

half-wave dipole antennas, 645  
 half-wave reflectionless slab, 165  
 Hall effect, 34, 148  
 Hallén equation with arbitrary field, 894  
 Hallén equations for coupled antennas, 939  
 Hallén integral equation, 857, 860  
   approximate kernel, 856  
   delta-gap input, 861  
   exact kernel, 856  
   plane-wave input, 861  
 harmonic time dependence, 13  
 Helmholtz equations, 366  
 Hertzian dipole antenna, 639  
 high resolution microscopy, 257  
 horn antennas, 730  
 horn design, 740  
 horn directivity, 737  
 horn radiation fields, 732  
 horn radiation patterns, 734  
 Huygens source, 669

impedance  
   mutual, 916  
   self, 916  
   transverse, 64, 242, 244, 364  
   wave, 46  
 impedance matching, 156, 476  
   balanced stubs, 505  
   Chebyshev transformer, 479  
   Chebyshev transformers, 225  
   conjugate matching, 476  
   double- and triple-stub tuners, 507  
   dual-band Chebyshev transformer, 485  
   flat line, 477  
   L-section matching network, 509  
   matching networks, 477  
   microstrip matching circuits, 496

one-section transformer, 501  
 Pi-section matching network, 512  
 quarter-wavelength transformer, 185, 479  
 quarter-wavelength with series section, 491  
 quarter-wavelength with shunt stub, 494  
 reversed matching networks, 519  
   single-stub tuner, 501  
   two-section transformer, 496  
 impedance matrix, 525  
 impedance transformers, 189  
 infrared bands, 951  
 inhomogeneous materials, 5  
 inhomogeneous waves, 64, 260  
 integral theorems, 952  
 intermodal dispersion, 6  
 internal reflection spectroscopy, 257  
 inverse power iteration, 845  
 ionospheric refraction, 285  
 isotropic radiator, 602  
  
 Kaiser window, 810, 839  
 kernel  
   approximate, 856  
   elliptic function representation, 873  
   exact, 856  
   numerical evaluation, 872  
   reduced, 856  
 King's four-term approximation, 871, 915  
 King's three-term approximation, 865, 910  
 Kirchhoff diffraction formulas, 680  
 knife-edge diffraction, 689  
 Kottler's formulas, 666  
 Kramers-Kronig dispersion relations, 6, 26, 34  
 Kubelka-Munk model, 472  
  
 L-section matching network, 509  
 layer recursions, 215, 303  
   backward, 216  
   forward, 212, 303  
 left-handed media, 7, 70, 294  
 lens antennas, 769  
 lenses, 719  
 Levinson recursion, *see* layer recursions  
 linear antennas, 637  
 linear prediction, 185  
 link budget calculation, 631  
 loop antennas, 653  
 Lorentz dielectric, 18  
 Lorentz force, 2  
 Lorentz transformations, 177, 972  
 Lorenz gauge condition, 572  
 loss tangent, 24, 58  
 lossless bounded real functions, 185  
 lossy media, 53  
 lossy media, weakly, 59  
 lossy multilayer structures, 304  
 low-noise, high-gain, amplifier, 625  
 lowest usable frequency (LUF), 286

Macneille polarizers, *see* reflective polarizers  
 magnetic currents, 661, 663  
 magnetic field, 1  
 magnetic flux density, 1  
 magnetic induction, 1  
 magnetic resonance, 138  
 magnetization, 4  
 magnetization current, 6  
 matched filter, 121  
 matching, *see* impedance matching  
 matching matrices, 156, 186  
 matching matrix, 246  
 matching networks, 477  
 material dispersion, 6  
 MATLAB functions:  
   Cin, cosine integral Cin, 921, 965  
   Ci, cosine integral Ci, 921, 965  
   Gi, Green's function integral, 920, 965  
   RLCmovie, reactive termination, 445  
   Si, sine integral, 921, 965  
   TDRmovie, time-domain reflectometry, 455  
   abp2, polar gain in absolute units, 930  
   abp, polar gain in absolute units, 605  
   abz2, azimuthal gain in absolute units, 930  
   abz, azimuthal gain in absolute units, 605  
   asinhc, inverse hyperbolic sinh, 841  
   binomial, binomial array, 826  
   blkrec, backward layer recursion, 221  
   blockmat, manipulate block matrices, 944  
   brewster, Brewster and critical angles, 350  
   bwidt, array beamwidth, 798  
   c2p, cartesian to phasor form, 565  
   chebarray, Dolph-Chebyshev array, 830  
   chebtr2, Chebyshev transformer, 229, 480  
   chebtr3, Chebyshev transformer, 229, 480  
   chebtr, Chebyshev transformer, 229, 480  
   dbp2, polar gain in dB, 930  
   dbp, polar gain in dB, 605  
   dbz2, azimuthal gain in dB, 778  
   dbz, azimuthal gain in dB, 605  
   dguide, TE modes in dielectric slab, 393  
   diff, diffraction integrals, 733, 963  
   dipdir, dipole directivity, 644  
   dipmovie, radiating dipole movie, 585  
   dipole, dipole gain, 646  
   dmax, dipole directivity, 646  
   dnv, elliptic function dn, 874  
   dolph2, Dolph-Chebyshev array, 834  
   dolph3, Dolph-Chebyshev array, 838  
   dolph, Dolph-Chebyshev array, 830  
   dsinc, double sinc function, 728  
   dslab, cutoff wavenumbers in slab, 393  
   dualband, dual-band transformer, 489  
   dualbw, dual-band bandwidth, 491  
   ellipE, elliptic integral of 2nd kind, 874  
   ellipK, elliptic integral of 1st kind, 874  
   ellipse, polarization ellipse, 52  
   fcs2, Fresnel integrals, 961

fcs, Fresnel integrals, 961  
 fresnel, Fresnel coefficients, 249, 349  
 frwrec, forward layer recursion, 221  
 gain1d, one-dimensional array gain, 774  
 gain2d, gain of 2D array of dipoles, 945  
 gain2s, gain of sinusoidal dipole array, 928  
 gin, input reflection coefficients, 537  
 gout, output reflection coefficients, 537  
 gprop, propagation of  $\Gamma$ , 419  
 grvmovie1, pulse propagation with  $vg < 0$ , 112  
 grvmovie2, pulse propagation with  $vg > c$ , 112  
 hband, horn bandedges, 733  
 hbasis, Hallén basis functions, 894  
 hcoupled2, coupled Hallén equations, 944  
 hcoupled, coupled Hallén equations, 944  
 hdelta, Hallén equation with delta-gap, 883  
 heff, horn aperture efficiency, 733  
 hfield, Hallén with arbitrary field, 896  
 hgain, horn gain patterns, 733  
 hmat, Hallén impedance matrix, 883  
 hopt, optimum horn design, 733  
 hsigma, horn  $\sigma$  parameter, 733  
 hwrap, wrapped impedance matrix, 883  
 impedmat, mutual impedance matrix, 927  
 imped, dipole impedance, 642  
 k2k, converts to King's primed form, 866  
 kernel, exact and approximate kernel, 874  
 kingeval, King's three-term evaluation, 870  
 kingfit, King's three-term fit, 870  
 king, Kings three-term approximation, 868  
 landev, vectorial Landen transformation, 874  
 lmatch, L-section transformer, 511  
 lmin, location of voltage min/max, 433  
 mstripa, microstrip analysis, 407  
 mstripr, microstrip synthesis, 407  
 mstrips, microstrip synthesis, 407  
 multbeam, multibeam array, 851  
 multidiel1, multilayers, simplified, 304  
 multidiel2, lossy multilayers, 305  
 multidiel, multilayer structures, 304, 354  
 multiline, response of multisection line, 479  
 n2r, reflection coefficients, 221  
 nfcirc, noise figure circles, 537  
 nfig, calculate noise figure, 537  
 omniband2, birefringent bandwidth, 355  
 omniband, omnidirectional bandwidth, 335  
 onesect, one-section transformer, 501  
 p2c, phasor to cartesian form, 565  
 pfld, solves Pocklington equation, 901  
 pi2t,  $\Pi$  to  $T$  transformation, 513  
 pmatch,  $\Pi$  matching network, 515  
 poly2, improved version of poly, 232, 830  
 prolmat, prolate matrix, 845  
 prol, prolate array, 845  
 pulse2movie, pulse on transmission line, 453  
 pulsemovie, pulse on transmission line, 443  
 quadr2, Gauss-Legendre quadrature, 972  
 quadr2s, Gauss-Legendre quadrature, 972

**quadrs** Gauss-Legendre quadrature, 760  
**quadrs**, Gauss-Legendre quadrature, 966  
**quadr**, Gauss-Legendre quadrature, 966  
**qwt1**, quarter-wavelength transformer, 494  
**qwt2**, quarter-wavelength transformer, 495  
**qwt3**, quarter-wavelength transformer, 495  
**r2n**, refractive indices, 221  
**rhombic**, rhombic antenna gain, 652  
**scan**, array scanning, 796  
**sector**, sector beam design, 812  
**sgain**, calculate power gains, 537  
**sgcirc**, stability and gain circles, 537  
**sinhc**, hyperbolic sinc, 841  
**smatch**, simultaneous conjugate match, 537  
**smithcir**, draw stability or gain circles, 537  
**smith**, draw a basic Smith chart, 537  
**snel**, refraction angle, 348  
**snv**, elliptic function sn, 874  
**sparam**, calculate stability parameters, 537  
**sq rte**, evanescent square root, 263  
**steer**, array steering, 796  
**stub1**, single-stub tuner, 504  
**stub2**, double-stub tuner, 508  
**stub3**, triple-stub tuner, 509  
**swr**, standing wave ratio, 429  
**t2pi**,  $T \rightarrow \Pi$  transformation, 513  
**taylor1p**, Taylor's one-parameter, 841  
**taylorbw**, Taylor's B-parameter, 841  
**taylornb**, Taylor's n-bar method, 848  
**travel**, traveling-wave antenna, 649  
**tsection**, T-section equivalent, 420  
**twosect**, two-section transformer, 189, 499  
**upulse**, pulse generation, 452  
**ustep**, unit-step generation, 453  
**vee**, vee antenna gain, 652  
**ville**, Villeneuve method, 850  
**vprop**, propagation  $V, I$ , 419  
**woodward**, Woodward-Lawson method, 814  
**yagi**, Yagi-Uda array, 935  
**zprop**, propagation of  $Z$ , 419  
maximum angle of refraction, 250, 349  
maximum available gain (MAG), 542  
maximum stable gain (MSB), 543  
maximum usable frequency (MUF), 286  
Maxwell's equations, 1  
  harmonic time dependence, 13  
  in terms of polarization, 6  
  source-free, 2  
Maxwell's stress tensor, 33  
metamaterials, 7, 294  
method of moments, 877  
  delta-basis with Galerkin, 885  
  delta-function basis, 880  
Galerkin method, 878  
NEC basis, 891  
point matching, 878  
pulse basis, 878, 884  
triangular basis, 889

weighting functions, 878  
**microstrip antennas**, 743  
**microstrip matching circuits**, 496  
**microwave amplifier design**, 544  
**microwave frequency bands**, 950  
**microwave oven**, 58  
**mirages**, 287  
**mobility**, 22  
**momentum conservation**, 33  
**momentum density**, 13  
**momentum flux**, 10  
**monopole antennas**, 646  
**moving boundary**  
  Fresnel drag, 179  
  oblique reflection from, 274  
  reflection and transmission from, 177  
**moving media**, 177  
**moving mirror**, 180  
**multibeam array design**, 850  
**multilayer optical film**, 359  
**multilayer structures**, 185, 302  
  at oblique incidence, 302  
  birefringent, 354  
  dielectric mirrors, 192, 332  
  energy conservation in, 214  
  equal-travel time, 208  
  lossy, 304  
  reflection frequency response of, 213  
  scattering matrix of, 214  
**multiple dielectric slabs**, 175  
**multiple reflections**, 173  
**multisection transmission lines**, 478  
**mutual impedance**, 916  
  
**narrow-beam, low-sidelobe array design**, 821  
**natural rotation**, 136  
**near fields of linear antennas**, 905, 908  
**negative index media**, 7, 30, 70, 294  
  Brewster angle in, 296  
  equivalent conditions, 72  
  propagation in, 70  
**negative-index media**  
  lossy, 72  
  perfect lens, 321  
  Snel's law, 294  
**network analyzer**, 526  
**noise bandwidth**, 617  
**noise figure**, 563, 622  
**noise figure circles**, 563  
**noise model of a device**, 621  
**noise power**, 617  
**noise temperature**, 563, 617  
  cellular base station, 618  
  of attenuator, 622  
  of cascaded devices, 623  
  sky, 618  
  system, 621  
**nonlinear materials**, 5

**normalized gain**, 604  
**numerical aperture**, 254  
**Nyquist frequency**  
  in multilayer structures, 209  
  
**Ohm's law**, 6, 21  
**ohmic power losses**, 3, 12, 14, 24  
**omnidirectional dielectric mirrors**, 192, 332  
**one-dimensional arrays**, 783  
**operating gain circles**, 557  
**operating power gain**, 541  
**optical fibers**, 253, 386  
  graded index, 293  
  numerical aperture, 254  
**optical filters**, 185  
  antireflection coatings, 187  
  dielectric mirrors, 192  
  narrow-band transmission, 203  
  shortpass and longpass, 202  
**optical manhole**, 252  
**optical rotation**, 134, 136  
**optically active media**, 131  
**optimum array directivity**, 794  
  
**p-polarization**, *see* polarization  
**parabolic reflector antennas**, 749  
**parasitic array**, 931  
**PBG**, *see* periodic bandgap structures  
**penetration depth**, 55  
  for evanescent waves, 251  
**perfect electric conductor**, 662  
**perfect lens**, 297, 321  
**perfect magnetic conductor**, 662  
**periodic bandgap structures**, 203  
  acoustic and vibration control, 203  
  Bloch wavenumber, 194  
  fiber Bragg gratings, 203  
  photonic crystals, 203  
  transmission lines and waveguides, 203  
**permeability**, 3  
**permittivity**, 3  
**phase delay**, 84  
**phase thickness**, 209, 303, 332  
**phase velocity**, 84  
**photonic crystals**, 203  
**physical constants**, 949  
**Pi-section matching network**, 512  
**plane wave incident on linear antenna**, 858  
**plane wave spectrum representation**, 706  
**plasma frequency**, 18  
**plasmas**, 25  
**plasmonics**, 274  
**Pocklington equation solution**, 899  
**Pocklington integral equation**, 857, 908  
**Poisson spot**, 715  
**Poisson's spot**, 715  
**polarization**, 4, 46, 241  
  Brewster angle, 258  
  
**charge density**, 8  
**linear, circular**, 132  
**TE, perpendicular, s-polarization**, 241  
**TM, parallel, p-polarization**, 241  
**polarization current and density**, 6  
**polarization ellipse**, 47  
**polarizers**, 133, 343  
  beam splitters, 343  
  reflective, 343, 358  
**polarizers, dichroic**, 138  
**polaroid materials**, 139  
**positive real functions**, 185  
**power density**, 601  
**power gain circles**, 554  
**power gains**, 539  
**power losses**, 3, 23  
**power losses in transmission lines**, 401  
**power losses per unit volume**, 3  
**power transfer in transmission lines**, 400, 423  
**power transfer in waveguides**, 367  
**power waves**, 545  
**Poynting vector**, 12, 14, 40  
**precursors**, 91  
**principal-value integrals**, 578  
**prisms**, 252  
**prolate array design**, 843  
**prolate matrix**, 794, 843  
**propagation**  
  and chirping, 102  
  in birefringent media, 131  
  in chiral media, 135  
  in dispersive media, 82  
  in good conductors, 60  
  in gyrotrropic media, 138  
  in negative index media, 70  
  in oblique directions, 61  
  in uniaxial and biaxial media, 133  
  in waveguides, 382  
  in weakly lossy media, 59  
  matrices, 152  
  oblique, in birefringent media, 139  
  of reflection coefficient, 153, 246  
  of wave impedance, 153, 246  
  transient and steady-state, 90  
**propagation filter**, 82  
**propagation impulse response examples**, 87  
**propagation matrices**, 186  
**propagator frequency response**, 83  
**propagator impulse response**, 83  
**pulse compression**, 112  
**pulse compression filters**, 114  
**pulse compression, and chirping**, 103  
**pulse propagation**, 82  
**pulse propagation, and group velocity**, 94  
**pulse spreading**, 6, 97  
  
**QPSK modulation**, 627  
**quadrupole radiation**, 658

quarter-wave reflectionless slab, 165  
 quarter-wave retarder, 133  
 quarter-wavelength transformer, 185, 479, 491, 494

radar, 80  
 radar equation, 632  
 radar jamming, 636  
 radar, chirp, 112  
 radiated power, 602  
 radiation field approximation, 595  
 radiation fields, 571, 590, 597  
 radiation fields from apertures, 666  
 radiation fields of magnetic currents, 665  
 radiation from apertures, 661  
 radiation from dipoles, 580  
 radiation from waveguide apertures, 726  
 radiation intensity, 601

isotropic, 602

radiation patterns of reflector antennas, 757  
 radiation potentials, 593  
 radiation resistance, 641, 642  
 radiation vector, 593

magnetic, 665

radiation vector of linear antennas, 639

radiative transfer, 472

radio interferometry, 787

radomes, 171

ray tracing, 283

Rayleigh-Sommerfeld diffraction theory, 703

rectangular apertures, 673

recursions, *see* layer recursions

refection coefficient, 153

reflectance, 165

reflectance spectroscopy, 472

reflected power, 159

reflection by moving boundary, 177

reflection coefficients, 157

for multilayer structures, 303

Fresnel, 246, 247

of multilayer structures, 185

transverse, 303

reflection response

forward recursion, 303

of multilayer structures, 186

reflectionless dielectric slab, 165

reflectionless matching, 476

reflective polarizers, 343

giant birefringent optics, 358

reflector antennas, 749

refraction

atmospheric, 288

ionospheric, 285

mirages, 287

refractive index, 4, 30, 244

in birefringent media, 141

transverse, 244, 303

refractive index model, 585

refractive index, complex, 54  
 relative permeability, 4  
 relative permittivity, 4  
 relativistic causality, 84  
 relaxation time, 11, 23  
 relaxation, charge, 22  
 resonant antennas, 643  
 resonant cavities, 384  
 retarded potentials, 573  
 retarders, 133  
 reversed matching networks, 519  
 RF spectrum, 950  
 rhombic antennas, 650

S-parameters, 525  
 available gain, 541  
 available gain circles, 557  
 generalized, 545  
 input and output reflection coefficients, 531  
 maximum available gain, 542  
 maximum stable gain, 543  
 microwave amplifier design, 544  
 network analyzers, 526  
 noise figure circles, 563  
 operating gain, 541  
 operating gain circles, 557  
 power flow, 529  
 power gain circles, 554  
 power gains, 539  
 power waves, 545  
 scattering matrix, 530  
 simultaneous conjugate matching, 549  
 stability circles, 533  
 stability criterion, 536  
 transducer gain, 541  
 traveling waves, 526  
 unilateral gain circles, 555

s-polarization, *see* polarization  
 satellite links, 629  
 scattering matrix, 158, 214  
 unitarity, 215  
 scattering parameters, 525  
 Schelkunoff's zero-placement, 805  
 Schur algorithm, 185  
 search radar, 633  
 sector beam array design, 808  
 Sellmeier equation, 20  
 sensors, chemical and biological, 257, 320  
 Shannon channel capacity, 627  
 SI units, 1, 949  
 simultaneous conjugate matching, 549  
 sine integrals, 960  
 single-stub tuner, 501  
 sinusoidal current approximation, 861  
 skin depth, 55  
 slef impedance, 916  
 small dipole antenna, 641  
 Smith chart, 434

Snel's law, 242, 282  
 Bouguer's law, 290  
 for lossy media, 248  
 in birefringent media, 353  
 in multilayer structures, 302  
 in negative-index media, 294  
 solid angle, 595  
 solitons, 6  
 Sommerfeld's conducting half-space solution, 697  
 spatial sampling theorem, 818  
 spherical coordinates, 593  
 square loop antennas, 657  
 stability circles, 533  
 standard atmosphere, 291  
 standing wave ratio, 428  
 standing-wave antennas, 641  
 stationary phase approximation, 963  
 Stratton-Chu diffraction formulas, 680  
 superluminal group velocity, 85, 105  
 surface current, 60  
 surface impedance, 60  
 surface plasmon resonance, 257, 312  
 surface plasmons, 271, 312  
 susceptibility, electric, magnetic, 4  
 system noise temperature, 621  
 system SNR, 622

Taylor line source array, 845

Taylor one-parameter array design, 839

Taylor's ideal line source, 821

Taylor's one-parameter line source, 821

Taylor-Kaiser arrays, 839

TE and TM impedance, 364

TE waves, 63

TE, TM, TEM modes, 363, 369

telegrapher's equations, 438, 457

thick glasses, 170

thin films, 185, 191, 204

thin-wire kernel, 856

time average

energy density, 14

ohmic losses, 14

Poynting vector, 14

time-domain reflection response, 173

time-domain reflectometry, 454

time-domain response of transmission lines, 438

TM waves, 63

total internal reflection, 249, 263

critical angle of incidence, 250

for birefringent media, 349

frustrated, 308

maximum angle of refraction, 250

transducer power gain, 541

transfer matrix, 186, 194, 209, 212, 525

transformers, *see* impedance matching

transition matrix, *see* transfer matrix

translational phase shift, 771

transmission coefficients, 157

transmission lines, 397  
 broadband terminations of, 185  
 cascaded lines, 453  
 coaxial lines, 408  
 coupled, 456  
 coupled telegrapher's equations, 457  
 crosstalk, 462  
 determination of load impedance, 430  
 distributed circuit model of, 415  
 equivalent electrostatic problem, 397  
 higher modes in, 412  
 impedance, inductance, capacitance, 398  
 lattice timing diagrams, 441  
 microstrip lines, 404  
 multisection lines, 478  
 open and short circuited lines, 425  
 parallel plate lines, 403  
 power losses, 401  
 power transfer, 423  
 reactive terminations, 443  
 reflection response, 417  
 rise time effects, 452  
 Smith chart, 434  
 standing wave ratio, 428  
 telegrapher's equations, 438  
 terminated lines, 420  
 Thévenin equivalent circuit, 426, 476  
 time-domain reflectometry, 454  
 time-domain response, 438  
 transient response, 439  
 transmitted power, 400  
 two-port equivalent circuit of, 419  
 two-wire lines, 413  
 wave impedance, 417  
 weakly coupled lines, 465  
 transmittance, 165  
 transmitted power, 159  
 transverse  
 fields, 242  
 Fresnel coefficients, 246, 247  
 impedance, 244  
 propagation matrices, 245  
 reflection coefficients, 245, 303  
 refractive index, 244, 303  
 wave impedance, 245  
 transverse impedance, 64, 242, 364  
 traveling wave antennas, 648  
 traveling waves, 526  
 triple-stub tuner, 507  
 two-port network, 525  
 two-section impedance transformer, 496  
 ultraviolet bands, 951  
 uniaxial media, 132  
 uniform apertures, 673  
 uniform arrays, 789  
 uniform plane waves, 36  
 unilateral gain circles, 555

units, 1  
vector diffraction for apertures, 684  
vector diffraction theory, 678  
vector identities, 952  
vector potential, 571  
vee antennas, 650  
velocity of light, 4  
very large array (VLA), 788  
very long base line array (VLBA), 788  
Villeneuve arrays, 849  
visible region, 785  
visible spectrum, 951  
Voyager spacecraft, 628  
  
wave equation, 37  
wave equations, 573  
wave impedance, 46, 153, 417  
    forward recursion, 304  
    of multilayer structures, 186  
wavefront, 43, 62  
    surfaces and rays, 279  
waveguide dispersion, 6  
Waveguides  
    cutoff wavenumber and frequency, 364  
    TE, TM, TEM modes, 363, 369  
waveguides, 361  
    attenuation, 367, 379  
    dielectric, 386  
    energy velocity, group velocity, 377  
    Helmholtz equations, 366  
    operating bandwidth, 376  
    power transfer, 367, 377  
    propagation model, 382  
    rectangular, 372  
    resonant cavities, 384  
    TE, TM impedance, 364  
wavelength division multiplexing, 5  
wavelength-division multiplexing, 185, 204  
waves  
    backward, 38  
    complex, 64, 260  
    evanescent, 251  
    forward, 38  
    in birefringent media, 140  
    in plasma, 150  
    inhomogeneous, 64, 260  
    monochromatic, 42  
    TE, TM, 63  
    uniform plane, 36, 53  
    Zenneck, 269  
Weyl representation, 956  
wire antennas, 637  
WMD, *see* wavelength division multiplexing  
Woodward-Lawson array design, 812  
Woodward-Lawson method, 819  
  
X-ray bands, 951

Yagi-Uda antennas, 934  
  
Zenneck surface wave, 269  
zero dispersion wavelength, 100  
zero-placement array design, 805