

Contents

1	Introduction to Radiowaves Propagation	1
1.1	Introduction	1
1.2	Earth Atmosphere Layers	2
1.3	Radio Frequency Bands	3
1.3.1	Electromagnetic Spectrum and Radiowaves	3
1.3.2	Role of Frequency in Radio Communications	3
1.3.3	Classification of Frequency Bands	4
1.4	Frequency Allocation	6
1.4.1	Introduction	6
1.4.2	Frequency Registration	6
1.4.3	ITU Regions for Frequency Allocation	6
1.4.4	Frequency Assignment	7
1.5	International Telecommunication Union	9
1.5.1	Objectives	9
1.5.2	Radio Regulations	10
1.5.3	ITU-R Recommendations	10
1.6	Types of Radiowave Propagation	10
1.7	Radio Services	12
1.8	Tropospheric Propagation	13
1.8.1	Troposphere Layer	13
1.8.2	Major Effects of Troposphere on Radiowaves	14
1.8.3	Standard Earth Atmosphere	14
1.8.4	Refraction of Radiowaves in Troposphere	16
1.8.5	<i>K</i> -Factor	17
1.9	Ionospheric Propagation	21
1.9.1	Introduction	21
1.9.2	Sub-layers of Ionosphere	22
1.9.3	Ionization and Plasma State	23
1.9.4	Ionosphere layer Classification	24
1.9.5	Ionospheric Phenomena	25

1.10	Free Space.....	26
1.10.1	Free-Space Loss.....	26
1.10.2	Power Flux Density	27
1.11	ITU-R Formulas	28
1.11.1	Point-to-Area Links	28
1.11.2	Point-to-Point Links	29
1.11.3	Radar Links	30
1.11.4	Power Flux Density	30
1.11.5	Conversion Relations	30
1.12	Equivalent Radiated Power.....	31
1.12.1	ERP and EIRP.....	31
1.12.2	Electric Field Intensity.....	32
1.13	Transmission Loss	33
1.13.1	Loss Terms in Radio Links	33
1.13.2	Basic Transmission Loss	34
1.13.3	System and Total Losses.....	35
1.14	Radio Noises	36
1.15	Exercises	37
2	Antennas and Passive Reflectors	41
2.1	Introduction	41
2.2	RF Transmission Devices	41
2.3	Antenna	42
2.3.1	Definition.....	42
2.3.2	Classification	43
2.3.3	Antenna Radome.....	43
2.3.4	Auxiliary Assemblies	44
2.4	Radio Power Radiation	45
2.4.1	Radiation Pattern	45
2.4.2	Radiation Power Density and Intensity	47
2.4.3	Effective Radiated Power	49
2.4.4	Electric Field Intensity.....	49
2.4.5	Radiated Peak Envelope	50
2.5	Antenna Basic Characteristics	51
2.5.1	Beamwidth	51
2.5.2	Directivity	53
2.5.3	Efficiency	54
2.5.4	Gain.....	55
2.5.5	Bandwidth	58
2.5.6	Polarization.....	58
2.5.7	Input Impedance	64
2.5.8	Power Handling Capability.....	64
2.5.9	Effective Area	64
2.5.10	Antenna Noise Temperature and G/T	65
2.5.11	Samples of Practical Antennas	68

2.6	Passive Repeaters	86
2.6.1	Radio-Relay Network	86
2.6.2	Objectives	86
2.6.3	Types of Passive Repeaters	86
2.6.4	Types of Passive Reflectors	87
2.6.5	Features	88
2.6.6	Link Configuration with Passive Repeaters	88
2.7	Gain and Radiation Pattern of Passive Reflectors	88
2.7.1	Near and Far Fields	89
2.7.2	Parabolic Reflector Antenna	90
2.7.3	Rectangular Flat Passive Reflector	91
2.7.4	Elliptical Flat Passive Reflector	94
2.8	Design Calculations	96
2.8.1	Gain of Reflector	97
2.8.2	Passive Reflector Efficiency	98
2.8.3	Effective Area of Reflector	98
2.8.4	Double Passive	98
2.8.5	Angles of Reflector Orientation	101
2.8.6	Near Field Reflector	103
2.8.7	Periscope	105
2.8.8	Radio Links with Passive Reflectors	107
2.9	Exercises	114
3	Radiowave Propagation in Satellite Communication	127
3.1	Introduction	127
3.1.1	Overall Objectives	127
3.1.2	Basic Concept	128
3.1.3	Main Applications	129
3.1.4	Features of Satellite Communications	130
3.1.5	Satellite Links	130
3.1.6	Frequency Bands	131
3.2	Geometry of Satellite Orbits	133
3.2.1	Earth Orbits	133
3.2.2	Satellite Coverage	137
3.2.3	Distances and Angles	145
3.3	Main Propagation Phenomena	152
3.3.1	Introduction	152
3.3.2	Main Phenomena	153
3.4	Clear Sky Losses	154
3.4.1	Free-Space Loss	154
3.4.2	Antenna Coupling Loss	156
3.4.3	Beam Spreading Loss	156
3.5	Effects of Troposphere Layer	157
3.5.1	Introduction	157
3.5.2	Atmospheric Gases and Vapors	158

3.5.3	Attenuation in Worst Month	161
3.5.4	Cloud and Fog Attenuation	165
3.5.5	Losses Due to the Sand and Dust Storms	165
3.5.6	Atmospheric Changes	166
3.6	Effects of Ionosphere	166
3.6.1	Introduction	166
3.6.2	Main Ionospheric Phenomena	167
3.6.3	Frequency Dependence	168
3.6.4	Refractivity Index	168
3.6.5	Pathlength of Radiowaves	171
3.6.6	Satellite Antenna Deviation Angle	173
3.6.7	Time and Frequency Variations	173
3.7	Radiowaves Polarization Variation	174
3.7.1	Main Parameters	175
3.7.2	Ionosphere Polarization Variation	176
3.7.3	Polarization Variation Due to Rain	178
3.7.4	Polarization Variation by Ice Particles	179
3.8	Effects of Local Environment	179
3.8.1	Building Entry Loss	180
3.8.2	Inside Vehicles	182
3.8.3	Reflection of Waves	182
3.9	Reliability of Satellite Links	183
3.10	Satellite Link Equation	184
3.10.1	Main Factors	184
3.10.2	Equivalent Isotropic Radiated Power	184
3.10.3	Merit of Reception System	184
3.10.4	Carrier-to-Noise Ratio	185
3.10.5	Coverage Footprints	187
3.11	Satellite Link Losses	188
3.11.1	Main Factors of the Losses	188
3.11.2	Loss Calculation	189
3.11.3	Received Signal Level	191
3.12	Satellite Uplink	192
3.12.1	Saturation Flux Density	193
3.12.2	Input Back-Off	194
3.12.3	TX Output Power of Earth Station	195
3.12.4	Nominal TX Power of Earth Station	195
3.13	Satellite Downlink	196
3.13.1	Received Carrier-to-Noise Ratio	196
3.13.2	Output Back-off	197
3.13.3	Output Power of Satellite TX	198
3.14	Total Carrier-to-Noise Ratio	198
3.14.1	Single-Carrier System	199
3.14.2	Multiple-Carrier System	199
3.14.3	CNR Calculations in Satellite Links	201

3.15	Safety Margin	202
3.15.1	Bit Error in Digital Communications	202
3.15.2	Minimum Carrier-to-Noise Ratio	203
3.15.3	Safety Margin	203
3.16	Exercises	205
4	Wireless Broadcasting	213
4.1	Introduction	213
4.2	Features of Broadcasting Services	214
4.3	Broadcasting Networks	214
4.3.1	Broadcasting with $\lambda \geq 10$ m	214
4.3.2	Broadcasting in Local Band	215
4.3.3	Broadcasting by Satellite	216
4.4	Frequency Bands	216
4.4.1	LF/MF/HF Frequency Band	216
4.4.2	VHF/UHF Frequency Band	217
4.4.3	Satellite Frequency Band	218
4.5	Broadcasting on the LF/MF/HF Band	219
4.5.1	General Phenomena	219
4.5.2	Particular Phenomena	219
4.6	Broadcasting Satellite System	220
4.6.1	Advantages of Satellite Broadcasting	220
4.6.2	Applications	220
4.6.3	Technical Parameters	221
4.6.4	Propagation of Satellite Radiowaves	224
4.7	Local Broadcasting in VHF/UHF Bands	227
4.7.1	Introduction	227
4.7.2	Waves Propagation of Public Broadcasting in VHF/UHF	229
4.7.3	Radiowaves Propagation Phenomena	230
4.7.4	Coverage Prediction	238
4.8	Path Loss of Radiowaves in VHF/UHF Bands	245
4.8.1	ITU-R Recommendations	245
4.8.2	The Propagation Curves	246
4.8.3	Basic Principles	251
4.8.4	Generalized Equations	254
4.8.5	Correction Factors	259
4.9	Exercises	268
5	Trans-Horizon Radiowaves Propagation	273
5.1	General Concept	273
5.1.1	Introduction	273
5.1.2	Trans-Horizon Communications	273
5.2	Trans-horizon Communications via Troposphere	275
5.2.1	Types of Tropospheric Propagation	275
5.2.2	Position of Troposcatters	276

5.3	Main Aspects and Applications	277
5.3.1	Main Aspects	277
5.3.2	Main Applications	277
5.3.3	Major Advantages.....	278
5.4	Troposphere Radiowaves Propagation	278
5.5	Geometry of Troposcattering Propagation	279
5.5.1	Introduction	279
5.5.2	The Radiowaves Path Profile	279
5.5.3	Geometrical Parameters	282
5.6	Received Signal Power	288
5.7	Climatic Classification of Earth.....	290
5.7.1	Equatorial Regions.....	290
5.7.2	Continental Subtropical Regions	291
5.7.3	Maritime Subtropical Regions.....	291
5.7.4	Desert Lands	291
5.7.5	Mediterranean Regions	291
5.7.6	Continental Temperate Regions	292
5.7.7	Maritime Temperate, Overland	292
5.7.8	Maritime Temperate, Oversea	292
5.7.9	Polar Regions	292
5.8	Calculations of Troposcatter Radiowaves Loss	293
5.8.1	Introduction	293
5.8.2	Radiowaves Propagation Loss.....	293
5.8.3	Worst Month Loss	297
5.9	Exercises	299
6	Propagation of Radar Waves	301
6.1	Introduction	301
6.1.1	Definition of Radar.....	301
6.1.2	Brief History	302
6.1.3	Applications	303
6.1.4	Categorization of Radars	303
6.1.5	Fixed and Mobile Radars	303
6.1.6	Radar Network Architecture.....	304
6.1.7	Basic Measurements by Radar	305
6.2	Main Aspects	306
6.2.1	Frequency Bands	306
6.2.2	Radar Transmission Power	307
6.2.3	Radar Cross Section	308
6.2.4	Scattering of Radar Waves.....	311
6.2.5	Basic Radar Equation	314
6.2.6	Signal-to-Noise Ratio	318
6.3	Propagation of Radar Waves	320
6.3.1	Propagation Medium.....	321
6.3.2	Effects of Frequency	322

6.3.3	Types of Radar Links	323
6.3.4	Effects of Atmosphere Layers	324
6.3.5	Effects of Earth	325
6.3.6	Free Space Loss	325
6.3.7	Doppler Effect	325
6.3.8	K -Factor and Radar Horizon	327
6.3.9	Multipath by Reflection	329
6.3.10	Polarization Losses	331
6.3.11	Target Losses	333
6.4	Radar Clutter	333
6.4.1	Introduction	333
6.4.2	Types of Clutters	334
6.4.3	Surface Clutter	335
6.4.4	Sea and Land Clutters	337
6.4.5	Volume Clutters	341
6.5	Radar Equation in Real Conditions	343
6.5.1	Noisy Media	343
6.5.2	Reflective Media on Multipath Reception	345
6.5.3	Interference and Jamming Condition	347
6.5.4	Reception in Clutter Condition	348
6.6	Radar Coverage	349
6.6.1	Introduction	349
6.6.2	System of Coordinates	349
6.6.3	Main Types of Radar Diagrams	351
6.6.4	Coverage Diagrams	351
6.6.5	Radar Site Selection	355
6.6.6	Radar Emissions	357
6.6.7	Safety Standard	358
6.7	Exercises	363
7	Short-Range Radio Communications	369
7.1	Introduction	369
7.2	General Considerations	370
7.2.1	Applications	370
7.2.2	Frequency Bands	371
7.2.3	Types of Radio Cells	371
7.2.4	Main Features	372
7.3	Quality Aspects of Short-Range Radio Links	372
7.3.1	Propagation Impairments	372
7.3.2	Outdoor Radiowave Propagation	374
7.3.3	Indoor Radiowaves Propagation	376
7.4	ITU-R Method for Short-Range Outdoor Radio Communications..	378
7.4.1	Introduction	378
7.4.2	Propagation Medium	378
7.4.3	Geometry of Radiowave Path	379

7.4.4	Radio Path Loss Calculations	383
7.4.5	Building Entry Loss.....	398
7.4.6	Multipath Models	399
7.4.7	Number of Signal Components.....	401
7.4.8	Polarization Characteristics.....	402
7.4.9	Characteristics of Direction of Arrival	403
7.4.10	Fading Characteristics	403
7.5	ITU-R Method for Indoor Radio Communications	405
7.5.1	Introduction	405
7.5.2	Propagation Medium.....	405
7.5.3	Propagation Impairments	406
7.5.4	Path Loss Models	407
7.5.5	Delay Spread Models	411
7.5.6	Effect of Polarization and Antenna Radiation Pattern.....	413
7.5.7	Effect of Transmitter and Receiver Siting	415
7.5.8	Effect of Building Materials, Furnishing, and Furniture ...	416
7.5.9	Effect of Movement of Objects.....	416
7.6	RF Leaky Cable.....	418
7.7	Exercises	420
8	Noise in Radiowave Propagation	423
8.1	Introduction	423
8.2	Noise in Radio Communications	423
8.2.1	Definition of the Noise and Its Source	423
8.2.2	Main Effects	425
8.3	Theoretical Principles	425
8.3.1	Thermal Noise Power	425
8.3.2	Noise Factor and Figure	426
8.3.3	Equivalent Noise Temperature	429
8.3.4	Antenna Equivalent Noise Temperature	430
8.4	Radio Noises	434
8.4.1	Source of Radio Noises	434
8.4.2	Noise Intensity Specifications and Their Interrelations ...	434
8.4.3	Noise Level in Terms of Frequency	437
8.4.4	Noise from Atmospheric Gases and the Earth's Surface ...	441
8.4.5	Man-Made Noise	443
8.4.6	Brightness Temperature from Extra-Terrestrial Sources ...	449
8.4.7	Atmospheric Noise Due to Lightning	452
8.4.8	Noise From Several Sources.....	453
8.5	Noise in Satellite Communications	456
8.5.1	Introduction	456
8.5.2	External Noise Sources in Satellite Communications	456
8.5.3	Galactic Noise.....	457
8.5.4	Solar Noise	457
8.5.5	Sky Noise.....	458

8.5.6	Ground Noise	460
8.5.7	Man-Made Noise	460
8.5.8	Antenna Thermal Noise	461
8.5.9	Equivalent Noise Temperature	462
8.6	Noise in Mobile Communications	467
8.6.1	Introduction	467
8.6.2	Natural Noises	468
8.6.3	Man-Made Noises	469
8.6.4	Traffic Noise	470
8.7	Exercises	472
9	Improvement Techniques in Radiowave Reception	475
9.1	Fading	475
9.2	Improvement in Radiowaves Reception	478
9.2.1	Fade Margin	478
9.2.2	Improvement Techniques	478
9.2.3	Combination of Received Signals	479
9.2.4	Improvement Parameter	481
9.3	Improvement Techniques in Mobile Radiowaves Reception	482
9.3.1	Overall Concepts and Definitions	482
9.3.2	BTS Location Diversity	485
9.3.3	Antenna Space Diversity	487
9.3.4	Frequency Diversity	491
9.3.5	Polarization Diversity	493
9.3.6	Field Component Diversity	493
9.3.7	Time Diversity	494
9.4	Improvement Techniques for Reception of LOS Waves	494
9.4.1	Introduction and General Concepts	494
9.4.2	Improvements Without Diversity Reception	495
9.4.3	Techniques for Diversity Reception	496
9.4.4	Antenna Vertical Space Diversity	498
9.4.5	Frequency Diversity of Radio Channels	500
9.4.6	Cross Band Diversity	503
9.4.7	Combined Diversity	504
9.4.8	Hybrid Diversity	506
9.4.9	Angle Diversity	506
9.4.10	Route Diversity	508
9.4.11	Adaptive Equalizer	508
9.4.12	ITU-R Method for Digital Radio Systems	510
9.5	Improvement Techniques for Reception of Satellite Radiowaves ...	511
9.5.1	Fading and Its Cause	511
9.5.2	Site Diversity of Ground Stations	511
9.6	Improvement Techniques for Reception of Troposcatter Radiowaves	517
9.6.1	Antenna Space Diversity	517

9.6.2	Frequency Diversity	518
9.6.3	Antenna Feed Angle Diversity	520
9.7	Exercises	520
A	Logarithmic System of Units	525
A.1	Introduction	525
A.2	Definition	525
A.3	Basic Formulas	526
A.4	Common Logarithmic Quantities	526
A.4	Principles of Logarithmic System of Units	527
A.5	Advantages of Logarithmic System of Units	527
B	ITU-R Recommendations P-Series.....	531
C	Acronyms	535
	References.....	541
	Index.....	545

Propagation Engineering in Radio Links Design

Ghasemi, A.; Abedi, A.; Ghasemi, F.

2013, XVIII, 549 p. 272 illus., Hardcover

ISBN: 978-1-4614-5313-0