Radar Remote Sensing of Planetary Surfaces Bruce A. Campbell

Contents

	Acknowledgments	<i>page</i> ix
1	Introduction	1
1.1	Radar remote sensing	1
1.2	Historical context	3
1.3	Rationale	10
	Outline of the book	11
2	Radar scattering terminology	13
	Outline	13
2.1	Basic terminology	13
2.2	Constitutive parameters	17
2.3	Electromagnetic waves in arbitrary media	19
2.4	Energy loss in a medium	20
2.5	Polarization	21
2.6	Coherence and power	24
	The Stokes vector	25
2.8	Polarization terminology	28
2.9	Reflection and refraction at a plane boundary	29
2.10	Emission from a surface	33
2.11	The radar equation	34
2.12	Polarization ratios	35
2.13	The scattering matrix	36
2.14	The Mueller and Stokes matrices	37
2.15	Polarization synthesis	40
	Summary	41
3	Roughness and dielectric properties	44
	Outline	44
3.1	Definition of roughness	45
3.2	Basic statistics of a rough surface	45

3.3	Correlation	49
3.4	The Fourier transform	51
3.5	The power spectrum, aliasing, and filtering	52
3.6	The importance of horizontal scale	57
3.7	Introduction to fractal concepts	58
3.8	Properties of self-affine continuous surfaces	62
3.9	Properties of surface and volume populations	65
3.10	Methods of topographic data collection	67
3.11	Dielectric properties of natural materials	70
3.12	Mixing of materials with different properties	75
3.13	Measuring the dielectric constant	79
	Summary	80
4	Radar data collection and analysis	82
	Outline	82
4.1	Antennas	83
4.2	Pulse compression techniques	85
4.3	Real-aperture radar (RAR)	88
4.4	Synthetic-aperture radar (SAR)	90
4.5	Planetary ranging and continuous-wave observations	95
4.6	Planetary delay-Doppler mapping	97
4.7	Effect of the ionosphere	104
4.8	Speckle	104
4.9	Radar scatterometers and altimeters	106
4.10	Interferometry	107
4.11	Geometric effects in radar mapping	110
4.12	Image geometric corrections	113
4.13	Data calibration	117
4.14	Image speckle and texture analysis	121
4.15	Structural and stereo mapping	127
	Summary	131
5	Theoretical treatment of scattering by rough surfaces	132
	Outline	132
5.1	Vector and scalar fields	133
5.2	Coherent and incoherent reflections	133
5.3	Scattering at a rough two-dimensional interface	135
5.4	Roughness criteria	137
5.5	Scattering by gently undulating surfaces	138
5.6	Scattering by slightly rough surfaces	145
5.7	Integral equation methods for rough surface scattering	151
5.8	Scalar model for coherent scattering by fractal rough surfaces	152

5.9	Scattering by collections of discrete objects	154
5.10	Numerical methods	161
5.11	The general nature of surface scattering	162
	Summary	166
6	Radar scattering from continuous rough surfaces	167
	Outline	167
6.1	Topographic and dielectric data for rough surfaces	168
6.2	Radar data for rough surfaces	173
6.3	Surface roughness	178
6.4	General backscatter properties of rough surfaces	180
6.5	Relationships between echo components	182
6.6	Very smooth surfaces and the small-perturbation model	187
6.7	Empirical models for the HH, VV, LR, and RL echoes	190
6.8	Empirical models for the HV, VH, LL, and RR echoes	193
6.9	Wavelength dependence in scattering from fractal surfaces	196
6.10	Blocky surfaces	196
6.11	Aeolian roughness	197
6.12	Scattering at high incidence angles	200
	Summary and implications for radar remote sensing	201
7	Radar scattering from collections of objects or layered terrain	203
	Outline	203
7.1	Statistical descriptions of rock-strewn surfaces	203
7.2	Example of a rock-strewn field site	208
7.3	Radar scattering from a rock-strewn surface	213
7.4	Radar scattering from sand dunes	219
7.5	Radar scattering from mantled rough surfaces	221
7.6	Examples of mantled surfaces	227
7.7	Radar scattering from volume populations	231
	Summary and implications for remote sensing	234
8	Planetary radar studies: the Moon, Mercury, and asteroids	235
	Outline	235
8.1	General properties of regoliths	235
8.2	Radar data for the Moon	239
8.3	Radar data for Mercury	241
8.4	Scattering models for a planetary regolith	241
8.5	The lunar mare regolith	247
8.6	Lunar pyroclastic deposits	254
8.7	Radar properties of lunar and mercurian impact craters	254
8.8	Ice at the poles of Mercury and the Moon	259
8.9	Radar observations of asteroids	262

8.10	Radar sounding	264
	Summary and future directions	268
9	Planetary radar studies: Venus and Mars	270
	Outline	270
9.1	The surface of Venus	271
9.2	Radar data for Venus	272
9.3	Surface properties of the Venus plains	278
9.4	Surface properties of venusian volcanoes	286
9.5	Impact craters on Venus	289
9.6	The nature of the Venus highlands	293
9.7	The surface of Mars	301
9.8	Radar data for Mars	302
9.9	Radar scattering from heavily cratered terrain and plains on	
	Mars	304
9.10	Surface properties of martian outflow and ejecta deposits	305
9.11	Surface properties of martian volcanoes	308
9.12	The martian polar caps	310
	Summary and future directions	311
	List of symbols	312
	References	316
	Index	329
	Color plate section facing page 150	