Contents

SU	MMA	ARY	1
1	INTRODUCTION		
	1.1	The Passive Radio Spectrum, 8	
	1.2	Prospects for Future Scientific Use of the Radio Spectrum, 12	
	1.3	The Interference Problem, 13	
	1.4	Interference Mitigation, 15	
	1.5	Enabling Scientific Uses of the Radio Spectrum, 16	
2	THI	E EARTH EXPLORATION-SATELLITE SERVICE	18
	2.1	Specific Application Areas of Passive Microwave Remote	
		Sensing, 23	
		Weather Forecasting and Monitoring, 24	
		Severe Weather and Disasters, 30	
		Climate and Global Change, 33	
		Resource Management, 41	
		Aviation, 43	
		Defense and Public Safety, 45	
		International Partnerships, 46	
		Education and Technology, 47	

2.2 Brightness Temperatures, Geophysical Measurements, and Missions, 48

Fundamentals of Microwave Radiometry for EESS Applications, 48

Measurement of Specific Geophysical Parameters, 52

- 2.3 Current and Future Space Missions, Activities, and Spectrum Usage, 53
- 2.4 Current and Future Non-Space-Based Activities and Spectrum Usage, 59
- 2.5 The Impact of Radio Frequency Interference on Earth Exploration-Satellite Service Observations, 61

Introduction to the Problem of Radio Frequency Interference: Immediate Impacts on EESS, 61

Evidence of Impact of Radio Frequency Interference on EESS Observations, 63

Potential Future Radio Frequency Interference and Its Impact on EESS Observations, 80

2.6 Summary of the Importance of and Risks to Continued Contributions of the Earth Exploration-Satellite Service in the Future, 86

3 THE RADIO ASTRONOMY SERVICE

3.1 The Scientific Impact of Radio Astronomy, 90
Origin of Planets and the Solar System, 90
Origin and Evolution of the Universe, 92
Pulsars and General Relativity, 95
Galactic Nuclei and Black Holes, 96
Galaxies, 101
Solar Physics and Space Weather, 102
Serendipity and the Transient Universe, 104
Summary, 105

- 3.2 Radio Observatories and Radio Telescopes, 106
- 3.3 Spectrum Requirements and Use, 113

 Continuum and Line Observations, 113

 Atmospheric Windows and Absorption Features, 115

 Current Radio Astronomy Service Allocations, 115

 Spectrum Use, 115
- 3.4 Sensitivity Requirements, 120 Sensitivity Limits, 122

88

4

5

3.5	Interference and Its Mitigation, 123	
	Examples of Interference in a Protected Band, 125 Mitigation, 127	
3.6	Importance of Radio Astronomy to the Nation, 130	
	Radio Interferometry, 130	
	Communications Disruptions, 131	
	Fundamental Physics, 132	
	Technology Development, 132	
	Precision Antennas, 132	
	Distributed Network Computing, 133	
	Education and Public Outreach, 133	
TEC	CHNOLOGY AND OPPORTUNITIES FOR THE MITIGATION	
OF I	RADIO FREQUENCY INTERFERENCE	135
4.1	Trends in Active Spectrum Usage, 136	
	Current Allocations, 136	
	Current Utilization Studies, 138	
4.2	Major Drivers of Spectrum Use, 145	
	Assessment of Trends in Spectrum Use for 2008–2015, 145	
	Third-Generation and Fourth-Generation Systems, 148	
	Unlicensed Uses of the Radio Frequency Spectrum, 149	
	Regulatory Changes That Impact Use, 151	
	Technology Changes That Impact Use, 153	
4.2	Summary, 155	
4.3	Unilateral Mitigation Techniques, 156	
4.4	Technologies for Unilateral Mitigation, 157	
4.4	Mitigation Through Cooperative Spectrum Usage, 168 Mitigation Costs, Limitations, and Benefits, 172	
4.3	Earth Exploration-Satellite Service (EESS), 173	
	Radio Astronomy Service (RAS), 173	
	Nature of the Costs of Radio Frequency Interference to	
	the EESS and the RAS, 174	
	Summary, 176	
	<i>California</i> 1, 1, 6	
FIN	DINGS AND RECOMMENDATIONS	177
5.1	Societal Value of the Passive Services, 178	
5.2	Characteristics of the Passive Spectrum Services, 180	
5.3	Threats to the EESS and the RAS from Unintentional Radio	
	Frequency Interference, 182	

5.4	Technology for Mitigation of Radio Frequency Interference	ence, 185
5.5	Protection of the EESS and the RAS, 187	
5.6	The Path Forward, 191	
5.7	Conclusion, 193	

APPENDIXES

A	Statement of Task	197
В	Biosketches of the Committee Members	199
C	Density of Interferers Equation	208
D	Analysis of Out-of-Band Emission Impacts to the EESS from §27.53	
	of the FCC Rules	210
E	Descriptions of Earth Exploration-Satellite Service Parameters	
	Related to Table 2.1	214
F	Acronyms and Abbreviations	221
G	Glossary	226