

Table of Contents

List of Symbols ix

List of Abbreviations xv

Preface xix

Acknowledgments xxv

1 Thermal Noise 1

Reference 3

2 Properties of Antennas 5

2.1 Absolute Black-Body Radiation 5

2.2 Brightness and Noise Temperature of Antennas 6

2.3 Near Field and Far Field 8

2.4 Directivity and Antenna Gain 10

2.5 Polarization 12

References 14

3 Two-Port Network Noise Figure and Equivalent Noise Temperature 15

3.1 Noise Figure of Radio Frequency Attenuator 16

3.2 Noise Bandwidth 17

3.3 System Noise Temperature 17

3.4 Figure of Merit G/T 18

References 19

4 Communication Equation 21

References 23

5 Wave Propagation 25

5.1 Free Space Wave Propagation 25

5.2 Influence of the Atmosphere 26

5.2.1 Precipitation Cloud in Front of Antenna 26

5.2.2 Ionosphere Influence 28

5.3 Wave Propagation by Reflection 30

References 31

6 Measuring the Figure of Merit G/T of the Receiving System 33

6.1 Y-Factor 33

6.2 Measuring G/T Using the Moon 36

6.3 Measuring G/T Using the Sun 40

6.4 Measuring G/T Using Other Space Objects 48

References 49

7 Parabolic Antennas 51

7.1 Reflector Geometry and Its Irradiation 51

7.1.1 Antenna with Rotationally Symmetric Reflector 52

7.1.2 Antenna with Offset Reflector 53

7.1.3 Antennas with Dual Optics 55

7.1.4 Accuracy of Parabolic Reflectors 56

7.2 Feeds 56

7.2.1 Open Circular Waveguide in 10 GHz Band 58

7.2.2 Open Circular Waveguide with Simple Choke 59

7.2.3 Scalar Feed 61

7.2.4 Horn with Rings 62

7.2.5 Horn for 10 GHz and Offset Reflector with $f/d = 0.8$ 63

7.2.6 Horn for 24 GHz and Offset Reflector with $f/d = 0.8$ 64

7.2.7 Horn for 24 GHz and Offset Reflector with $f/d = 0.6$ 66
7.2.8 Standard Horn for 1.3 GHz and Offset Reflector with $f/d = 0.8$ 68
References 71

8 High-Frequency Transmission Lines – Waveguides 73

8.1 Rectangular Waveguides 75
8.1.1 Reactance Elements in a Rectangular Waveguide 77
8.2 Circular Waveguides 80
8.3 Coaxial Transmission Lines 82
8.4 Planar Transmission Lines 84
8.5 Nonreciprocal Microwave Lines 86
References 92

9 Microwave Receivers 93

9.1 Low-Noise Amplifiers 98
9.1.1 Noise Matching 100
9.1.2 Cooled Amplifiers 100
9.1.3 Measurement of Noise Figure 104
9.1.4 Low-Noise Amplifier for 1.3 GHz 109
9.1.5 Low-Noise Amplifier for 10 GHz 117
References 120

10 Local Oscillators 121

10.1 Classification of Frequency Synthesizers 122
10.1.1 Coherent and Incoherent Synthesizers 122
10.1.2 Synthesizers with Direct and Indirect Synthesis 122
10.2 Direct Digital Frequency Synthesizers – DDS 123
10.2.1 Basic Description 123
10.2.2 Spectral Properties of DDS 124
10.3 Phase-Locked Loop Synthesizers 128
10.3.1 Time and Frequency Domain Description of a Phase-Locked Loop 128
10.3.2 Order and Type of Phase-Locked Loop 132
10.3.3 Phase-Locked Loop Synthesizers 132
10.3.4 Phase-Locked Loop Stability 133
10.3.5 Classification of Phase-Locked Loops 133
10.3.6 Spectral Properties of PLL Synthesizers 134
10.3.7 Allan's Variance 136
10.3.8 Circuitry of Modern PLL Synthesizers 138
10.3.9 Oscillators 139
10.3.10 Phase Frequency Detectors – PFD 141
10.3.11 Frequency Dividers 142
10.3.12 Loop Filters 143
10.4 Direct Digital Synthesizer with AD9951EP 145
10.5 Frequency Synthesizer for Microwave Devices 147
References 151

11 Microwave Transmitters 153

11.1 UHF Band Power Amplifier 300 W 154
11.2 X-Band Power Amplifiers 157
11.2.1 Single-Stage X-Band 4 W Power Amplifier 160
11.2.2 X-Band 20 W Power Amplifier 161
11.2.3 X-Band 50 W Power Amplifier 161

11.2.3.1 Calculation of Cooling 167

References 173

12 Communication by Lunar Surface Reflection 175

12.1 Lunar Surface as a Reflecting Surface 175

12.1.1 Reflected Signal Spectrum Broadening 176

12.1.2 Doppler Shift 177

12.1.3 Polarization of Signals 178

12.2 Digital Communication 179

12.2.1 Jt 65 180

12.2.2 Jt 4 180

12.2.3 Qra 64 181

12.2.4 Q 65 183

12.3 Parameters of Communication Devices 185

12.3.1 Antennas 186

12.3.2 System Noise Temperature 187

12.3.3 Echo 187

12.3.4 Accuracy and Stability of Frequency 192

12.3.5 Doppler Shift Compensation 193

12.4 Conclusion 194

References 194

13 Radio Communication with Interplanetary Spacecrafts 197

13.1 Terrestrial Segment for Deep Space Communication 197

13.2 Interplanetary Spacecrafts 200

13.2.1 Voyager 200

13.2.2 Cassini-Huygens 204

13.2.3 New Horizons 205

13.2.4 Mars Odyssey and Reconnaissance Orbiter 207

13.2.5 Spacecrafts at Lagrange Points 207

References 208

14 Conclusion 209

Index 211