

# Contents

	<b>Preface</b>	<b><i>xiii</i></b>
	<b>Part I</b>	
	<b>Radio Interferometer</b>	<b>1</b>
<b>1</b>	<b>Overview of Part I: Radio Interferometer</b>	<b>3</b>
<b>2</b>	<b>Receiving Antenna</b>	<b>7</b>
2.1	Receiving Points and the Baseline	7
2.2	Reference Point	8
2.3	Polarization	11
2.4	Sidelobe	12
2.5	Mechanical Stability	12
<b>3</b>	<b>Receiving Equipment</b>	<b>13</b>
3.1	Frequency Conversion	13
3.2	Receiving Routes	14

3.3	Phase Stability	16
3.4	Reference Correction	17
3.5	Cable Stability Condition	19
3.6	Reference Coupler	20
	Reference	21
<b>4</b>	<b><u>Phase Detection</u></b>	<b>23</b>
4.1	Direct Phase Measurement	23
4.2	Separate Measurement	24
4.3	Fourier Transform	26
4.4	Problem of Image Spectrum	27
4.5	Signal Processing for Phase Measurement	28
4.6	Noise Reduction	32
4.7	Tracking Nonbeacon Signals	35
	Reference	37
	Appendix 4A: Window and Phase Measurement	38
4A.1	Beacon Measurement	38
4A.2	Nonbeacon Measurement	39
<b>5</b>	<b><u>Signal, Noise, and Precision</u></b>	<b>41</b>
5.1	Required SNR	41
5.2	Signal Power and Noise Power	42
5.3	Beacon Downlink Budget	45
5.4	Tracking a Weak Signal	46
5.5	Estimates in PFD	47
	Reference	49

<b>6</b>	<b><u>Error Factors</u></b>	<b>51</b>
6.1	Baseline Error	51
6.2	Phase Ambiguity	53
6.3	Atmospheric Refraction	55
6.4	Effect of Rainwater	57
	Reference	57
<b>7</b>	<b><u>Design and Installation</u></b>	<b>59</b>
7.1	System Layout	59
7.2	Reflecting Interferometer	60
	<b>Part II</b>	
	<b><u>Geostationary Satellite Orbit</u></b>	<b>65</b>
<b>8</b>	<b><u>Overview of Part II: Geostationary Satellite Orbit</u></b>	<b>67</b>
	Reference	69
<b>9</b>	<b><u>Kepler's Laws</u></b>	<b>71</b>
9.1	Kepler's First Law	71
9.2	Kepler's Second Law	73
9.3	Kepler's Third Law	74
9.4	Physical Meanings	75
9.5	Significance of Kepler's Laws	80
<b>10</b>	<b><u>Near-Stationary Orbit</u></b>	<b>83</b>
10.1	Geostationary and Near-Stationary Orbits	83
10.2	Orbit with Small Eccentricity	84
10.3	Motion Due to Small Eccentricity	86
10.4	Motion Due to Nonstationary Radius	89

10.5	Motions in an Orbital Plane	90
10.6	Motion Perpendicular to an Orbital Plane	91
10.7	Relative Position Coordinates	93
	Reference	95
Appendix 10A: Width of Figure 8-Like Locus		95
<b>11</b>	<b><u>Changing the Orbit</u></b>	<b>97</b>
11.1	Orbital Energy	97
11.2	In-Plane Orbital Changes	99
11.3	In-Plane Orbital Maneuver	101
11.4	Inclination Maneuver	103
<b>12</b>	<b><u>Orbital Perturbations</u></b>	<b>107</b>
12.1	Perturbing Forces	107
12.2	Nonspherical Shape of the Earth	108
12.3	Patterns of Longitudinal Drift	111
12.4	Solar Radiation Pressure	113
12.5	Position of the Sun	117
12.6	Long-Term Effect	118
12.7	Gravity of the Sun	120
12.8	Tilting of the Orbital Plane	122
12.9	Gravity of the Moon	125
12.10	Sun-Moon Combined Effect	128
	Reference	129

<b>13</b>	<b><u>Station Keeping</u></b>	<b>131</b>
13.1	EW Keeping for Drift-Rate Control	131
13.2	EW Keeping for Eccentricity Control	133
13.3	Combined EW Keeping	136
13.4	NS Keeping	137
13.5	Factors Depending on Satellites	138
	Reference	141
<b>14</b>	<b><u>Overcrowding and Regulations</u></b>	<b>143</b>
14.1	Orbital Regulations	143
14.2	Problem of Overcrowding	145
	Reference	145
	<b>Part III</b>	
	<b><u>Interferometric Tracking</u></b>	<b>147</b>
<b>15</b>	<b><u>Overview of Part III: Interferometric Tracking</u></b>	<b>149</b>
<b>16</b>	<b><u>Tracking and Orbit Estimation</u></b>	<b>151</b>
16.1	General Concept	151
16.2	Styles of Orbit Estimation	152
16.3	Choice of Estimation Style	154
16.4	Software Units	155
16.5	Meaning of Orbit Estimation	157
16.6	Tracking Using an Interferometer	158
	Reference	160
<b>17</b>	<b><u>Azimuth-Elevation Tracking</u></b>	<b>161</b>
17.1	Azimuth-Elevation Angles	161

17.2	Azimuth-Elevation Interferometer	163
17.3	Detection Unit Vector of a Baseline	164
17.4	Orbit Estimation	166
17.5	Accuracy Considerations	168
17.6	Nonhorizontal Baseline	168
<b>18</b>	<b><u>Longitude Tracking</u></b>	<b>171</b>
18.1	Satellite Longitudes	171
18.2	Longitude-Monitoring Interferometer	172
18.3	Orbit Estimation	173
18.4	Interferometer Setup	175
18.5	Monitoring Examples	175
18.5.1	Single Satellite	175
18.5.2	Two Satellites	177
18.5.3	Different-Band Satellites	179
	Reference	180
<b>19</b>	<b><u>Range-Azimuth Tracking</u></b>	<b>181</b>
19.1	Combined Tracking for Orbit Estimation	181
19.2	Merit of Combined Tracking	183
19.3	Interferometer Hardware and Performance	183
19.4	Station Keeping with Safety Monitoring	185
	Reference	186
<b>20</b>	<b><u>Differential Tracking</u></b>	<b>187</b>
20.1	Differential Tracking Concept	187
20.2	Interferometer Hardware	188

20.3	Orbit Estimation	190
20.4	Possible Applications	191
	Reference	192
<b>21</b>	<b><u>Rotary-Baseline Interferometer</u></b>	<b>193</b>
21.1	Rotary Baseline	193
21.2	Rotary Baseline with Mirrors	195
21.3	Rotary-Baseline Interferometer	196
21.4	Operation and Data Processing	199
21.5	Orbit Estimation	203
21.6	Long-Term Monitoring	205
21.7	Error Considerations	207
21.8	Error Calibration	209
21.9	Nongeometrical Error	210
	Reference	212
<b>22</b>	<b><u>Geolocation Interferometer</u></b>	<b>213</b>
22.1	Geolocation: Principle and Problem	213
22.2	Weak-Signal Detection	215
22.3	Delay Limit and Delay Line	217
22.4	Correlation Processing	219
22.5	Time-Integration Effect	220
22.6	Problem of Satellite-Transponder Phase	222
22.7	Phase Measurement Accuracy	223
22.8	Locating the Earth Station	224
22.9	Transponder Frequency Errors	228

22.10	Orbital Information	228
22.11	Quick Orbit Estimation	229
	Reference	230
	<b><u>About the Author</u></b>	<b>231</b>
	<b><u>Index</u></b>	<b>233</b>