

1	Introduction	1
1.1	General	1
1.2	The Geostationary Orbit in Math	3
1.3	The Status of Geostationary Satellites	5
1.4	The Framework of the Book	6
	References	7
2	Orbit Motion Foundations	9
2.1	Introduction	9
2.2	The Motion of the Earth	10
2.2.1	A Solar Day	10
2.2.2	A Sidereal Day	11
2.2.3	Equinox Direction	12
2.2.4	Primary Longitude	14
2.2.5	Local Solar Time	15
2.2.6	Polar Motion	16
2.2.7	Precession Motion	18
2.2.8	Nutation Motion	19
2.3	Time System	24
2.3.1	Seconds in a Day	25
2.3.2	Sidereal Time and Universal Time	25
2.3.3	Julian Days and Modified Julian Days	26
2.3.4	Greenwich Sidereal Time	27
2.3.5	International Atomic Time	28
2.3.6	Coordinated Universal Time	30
2.3.7	Local Time	31
2.3.8	Ephemeris Time	31
2.3.9	GPS Time	33
2.3.10	Time System Summaries	33

2.4	Reference System	35
2.4.1	Background and General Definitions	36
2.4.2	J2000.0 Earth-Centered Inertial System	37
2.4.3	The Mean Equator and Equinox	38
2.4.4	The True Equator and Equinox	40
2.4.5	The Greenwich Meridian-Fixed System	42
2.4.6	International Terrestrial Reference System	44
2.4.7	Global Geodetic System	46
2.4.8	Local Tangential Coordinate System	48
2.4.9	Orbit RTN Coordinate System	51
2.4.10	Satellite-Fixed Orbit Coordinate System	52
2.4.11	Satellite-Fixed East/South/Down Coordinate Frame	53
2.4.12	Satellite Body Coordinate System	54
2.5	The Kepler Orbit	60
2.5.1	Kepler Orbit Elements	60
2.5.2	The Kepler Orbit with Motion States	61
2.5.3	The Kepler Orbit with Reference System	66
2.5.4	The Station Keeping Element	67
	References	72
3	The Motion of Geostationary Satellite	73
3.1	Introduction	73
3.2	The Geostationary Orbit in Inertial Space	74
3.3	The Geostationary Orbit Relative to the Earth	78
3.3.1	Linearization of Geocentric Distance	78
3.3.2	Linearization of the True Anomaly	79
3.3.3	Linearization of Right Ascension and Longitude	81
3.3.4	Linearization of Relative Declination	83
3.4	The Truth of “8”-Shape Subsatellite	84
3.5	The Relative Motion with Nominal Longitude	87
3.5.1	The Orbit Motion Projected on the Equator Plane	88
3.5.2	The Orbit Motion Projected on the Meridian Plane	89
3.5.3	Relative Motion Projected on the Local Horizontal Plane	92
4	Geostationary Orbit Perturbation	99
4.1	Introduction	99
4.2	Natural Evolution Motion Scenery	100
4.3	Lagrange Equation for Station Keeping Elements	103
4.3.1	Lagrange Equation for the Drift Vector	104
4.3.2	Lagrange Equation for the Eccentricity Vector	105
4.3.3	Lagrange Equation for the Inclination Vector	107
4.4	The Earth’s Non-spherical Perturbation	109
4.4.1	The Earth’s Non-spherical Potential Function	109
4.4.2	Real Geostationary Orbit	111
4.4.3	Semi-major Axis Evolution	115

4.4.4	Longitude Drift Evolution	122
4.4.5	Mean Longitude Evolution	123
4.4.6	Inclination Vector Evolution	130
4.4.7	Eccentricity Vector Evolution	133
4.5	The Solar and Lunar Perturbation	135
4.5.1	The Lunar and Solar Potential Function	138
4.5.2	Semi-major Axis Evolution	140
4.5.3	Longitude Evolution	146
4.5.4	Eccentricity Evolution	147
4.5.5	Inclination Evolution	149
4.5.6	Solar-Lunar Ephemeris	159
4.6	The Solar Radiation Perturbation	160
4.6.1	Solar Radiation Pressure Potential Function	166
4.6.2	Longitude Drift Evolution	166
4.6.3	Eccentricity Evolution	169
4.6.4	Inclination Evolution	172
4.6.5	Eclipses of the Solar by the Earth and Moon	173
4.7	Perturbation Summaries	175
	References	176
5	Harmonic Analysis Geostationary Orbit	177
5.1	Introduction	177
5.2	Harmonic Analysis	178
5.3	Basic Functions and Periodic Expansion	179
5.4	Determining the Coefficients with SVD Method	179
5.5	Longitude and Drift Harmonics	182
5.6	Eccentricity Vector Harmonics	186
5.7	Inclination Vector Harmonics	190
	References	195
6	Correction Geostationary Orbit	197
6.1	Introduction	197
6.2	Relative Motion Equation	198
6.2.1	Radial Equation	198
6.2.2	Tangential Equation	198
6.2.3	Normal Equation	199
6.3	Orbit Correction Equation	200
6.4	Radial Impulse	201
6.5	Tangential Impulse	205
6.6	Normal Impulse	209
6.7	Continuous Thrust	211
6.8	Onboard Thrust Configuration	214
7	Maintaining Geostationary Orbit	217
7.1	Introduction	217
7.2	North/South Station Keeping Strategy	220

7.2.1	General Background	220
7.2.2	Inclination Dead Band Allocation	222
7.2.3	Inclination Maneuver Strategy	223
7.2.4	Maneuver Calculation	223
7.2.5	Maneuver Planning	225
7.2.6	Case Study and Simulation	227
7.3	East/West Station Keeping Strategy	230
7.3.1	General Background	230
7.3.2	Longitude Dead Band Allocation	235
7.3.3	Longitude Maneuver Strategy	237
7.3.4	Eccentricity Maneuver Strategy	239
7.3.5	Maneuver Calculation	249
7.3.6	Single-Pulse Maneuver Planning	254
7.3.7	Bi-Pulse Maneuver Planning	263
7.3.8	Tri-Pulse Maneuver Planning	277
	References	282
8	Collocation Prototypes and Strategies	283
8.1	Introduction	283
8.2	Reference and Notation	285
8.3	Collocation Relative Motion	286
8.4	Collocation Principles	288
8.5	Complete Longitude Separation	289
8.6	Eccentricity Separation	292
8.6.1	Absolute Eccentricity Offsetting Strategy	294
8.6.2	Relative Eccentricity Offsetting Strategy	299
8.6.3	Evaluation of Eccentricity Separation Strategy	300
8.6.4	Solar Leading Eccentricity Control Strategy	304
8.7	Combined Eccentricity and Inclination Separation	311
8.7.1	The Mathematical Prototype of E/I Strategy	311
8.7.2	Inclination Distribution Strategy	314
8.7.3	Inclination Maintenance Strategy	315
8.8	A Bi-Satellite E/I Combined Separation Method	318
8.9	A Coordinated E/I Combined Separation Method	323
8.10	A Tri-Satellite Hybrid <i>e-i</i> Separation Method	326
8.11	Safety Analysis and Collision Warning	331
	References	334