

JPL DEEP SPACE COMMUNICATIONS AND NAVIGATION SERIES

# **RADIOMETRIC TRACKING TECHNIQUES FOR DEEP SPACE NAVIGATION**



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# Radiometric Tracking Techniques For Deep Space Navigation

**Dave Doody**



## **Radiometric Tracking Techniques For Deep Space Navigation:**

**Radiometric Tracking Techniques for Deep-Space Navigation** Catherine L. Thornton, James S. Border, 2003-02-05

Radiometric Tracking Techniques for Deep Space Navigation focuses on a broad array of technologies and concepts developed over the last four decades to support radio navigation on interplanetary spacecraft. In addition to an overview of Earth based radio navigation techniques, the book includes a simplified conceptual presentation of each radiometric measurement type, its information content, and the expected measurement accuracy. The methods described for both acquiring and calibrating radiometric measurements also provide a robust system to support guidance and navigation for future robotic space exploration.

**Radiometric Tracking Techniques for Deep-Space Navigation** Catherine L. Thornton, James S. Border, United States. National Aeronautics and Space Administration, Jet Propulsion Laboratory (U.S.), 2000

**Radiometric Tracking Techniques for Deep-Space Navigation** Catherine L. Thornton, James S. Border, 2005-02-18. Radiometric Tracking Techniques for Deep Space Navigation focuses on a broad array of technologies and concepts developed over the last four decades to support radio navigation on interplanetary spacecraft. In addition to an overview of Earth based radio navigation techniques, the book includes a simplified conceptual presentation of each radiometric measurement type, its information content, and the expected measurement accuracy. The methods described for both acquiring and calibrating radiometric measurements also provide a robust system to support guidance and navigation for future robotic space exploration.

*Radio Science Techniques for Deep Space Exploration* Sami W. Asmar, 2022-03-23. Explore the development and state of the art in deep space exploration using radio science techniques. In *Radio Science Techniques for Deep Space Exploration*, accomplished NASA JPL researcher and manager Sami Asmar delivers a multi-disciplinary exploration of the science, technology, engineering, mission operations, and signal processing relevant to deep space radio science. The book discusses basic principles before moving on to more advanced topics that include a wide variety of graphical illustrations and useful references to publications by experts in their respective fields. Complete explanations of changes in the characteristics of electromagnetic waves and the instrumentation and technology used in scientific experiments are examined. *Radio Science Techniques for Deep Space Exploration* offers answers to the question of how to explore the solar system with radio links and better understand the interior structures, atmospheres, rings, and surfaces of other planets. The author also includes thorough introductions to radio science techniques and systems needed to investigate planetary atmospheres, rings, and surfaces. Comprehensive explorations of planetary gravity and interior structures, as well as relativistic and solar studies. Practical discussions of instrumentation, technologies, and future directions in radio science techniques. Perfect for students and professors of physics, astronomy, planetary science, aerospace engineering, and communications engineering. *Radio Science Techniques for Deep Space Exploration* will also earn a place in the libraries of engineers and scientists in the aerospace industry.

**Spacecraft Optical Navigation** William M. Owen,

Jr.,2024-10-11 UNIQUE RESOURCE EXPLORING HOW SPACECRAFT IMAGERY PROVIDES PROFESSIONALS WITH ACCURATE ESTIMATES OF SPACECRAFT TRAJECTORY WITH REAL WORLD EXAMPLES AND DETAILED ILLUSTRATIONS

Spacecraft Optical Navigation provides detailed information on the planning and analysis of spacecraft imagery to help determine the trajectory of a spacecraft The author an experienced engineer within the field addresses the entirety of celestial targets and explains how a spacecraft captures their imagery Aimed at professionals within spacecraft navigation this book provides an extensive introduction and explains the history of optical navigation reviewing a range of optical methods and presents real world examples throughout With the use of mathematics this book discusses everything from the orbits sizes and shapes of the bodies being imaged to the location and properties of salient features on their surfaces Specific sample topics covered in Spacecraft Optical Navigation include History of various past spacecraft including Mariner and Viking Voyager Galileo NEAR Shoemaker and Cassini and flight hardware star catalogs and stereophotoclinometry Cameras covering the gnomonic projection and deviations from it creation of a digital picture picture flattening and readout smears Modeling optical navigation observables covering apparent directions to an object star and limbs or terminators and orientation of cameras Obtaining optical navigation observables covering centerfinding for stars and resolved and unresolved bodies and using opnav data in orbit determination Spacecraft Optical Navigation is an ideal resource for engineers working in spacecraft navigation and optical navigation to update their knowledge of the technology and use it in their day to day The text will also benefit researchers working with spacecraft particularly in navigation and professors and lecturers teaching graduate aerospace courses

*Deep Space Optical Communications* Hamid Hemmati,2006-06-05 A quarter century of research into deep space and near Earth optical communications This book captures a quarter century of research and development in deep space optical communications from the Jet Propulsion Laboratory JPL Additionally it presents findings from other optical communications research groups from around the world for a full perspective Readers are brought up to date with the latest developments in optical communications technology as well as the state of the art in component and subsystem technologies fundamental limitations and approaches to develop and fully exploit new technologies The book explores the unique requirements and technologies for deep space optical communications including Technology overview link and system design drivers Atmospheric transmission propagation and reception issues Flight and ground terminal architecture and subsystems Future prospects and applications including navigational tracking and light science This is the first book to specifically address deep space optical communications With an increasing demand for data from planetary spacecraft and other sources it is essential reading for all optical communications telecommunications and system engineers as well as technical managers in the aerospace industry It is also recommended for graduate students interested in deep space communications

**Proceedings of the 27th Conference of Spacecraft TT&C Technology in China** Rongjun Shen,Weiping Qian,2014-10-06 This book collects selected papers from the 27th Conference of Spacecraft TT C Technology

in China held in Guangzhou on November 9 12 2014 The book features state of the art studies on spacecraft TT C in China with the theme of Wider Space for TT C To meet requirements of new space endeavors especially China s deep space programs China s spacecraft TT C systems shall go farther measure more accurately and control better with higher efficacy Researchers and engineers in the field of aerospace engineering and communication engineering can benefit from the book

**CubeSat Antenna Design** Nacer Chahat,2021-01-07 Presents an overview of CubeSat antennas designed at the Jet Propulsion Laboratory JPL CubeSats nanosatellites built to standard dimensions of 10cm x 10 cm x cm are making space based Earth science observation and interplanetary space science affordable accessible and rapidly deployable for institutions such as universities and smaller space agencies around the world CubeSat Antenna Design is an up to date overview of CubeSat antennas designed at NASA s Jet Propulsion Laboratory JPL covering the systems engineering knowledge required to design these antennas from a radio frequency and mechanical perspective This authoritative volume features contributions by leading experts in the field providing insights on mission critical design requirements for state of the art CubeSat antennas and discussing their development capabilities and applications The text begins with a brief introduction to CubeSats followed by a detailed survey of low gain medium gain and high gain antennas Subsequent chapters cover topics including the telecommunication subsystem of Mars Cube One MarCO the enabling technology of Radar in a CubeSat RainCube the development of a one meter mesh reflector for telecommunication at X and Ka band for deep space missions and the design of multiple metasurface antennas Written to help antenna engineers to enable new CubeSat NASA missions this volume Describes the selection of high gain CubeSat antennas to address specific mission requirements and constraints for instruments or telecommunication Helps readers learn how to develop antennas for future CubeSat missions Provides key information on the effect of space environment on antennas to inform design steps Covers patch and patch array antennas deployable reflectarray antennas deployable mesh reflector inflatable antennas and metasurface antennas CubeSat Antenna Design is an important resource for antenna microwave engineers aerospace systems engineers and advanced graduate and postdoctoral students wanting to learn how to design and fabricate their own antennas to address clear mission requirements

**Spaceborne Antennas for Planetary Exploration** William A. Imbriale,2006-08-08 JPL spacecraft antennas from the first Explorer satellite in 1958 to current R D Spaceborne Antennas for Planetary Exploration covers the development of Jet Propulsion Laboratory JPL spacecraft antennas beginning with the first Explorer satellite in 1958 through current research and development activities aimed at future missions Readers follow the evolution of all the new designs and technological innovations that were developed to meet the growing demands of deep space exploration The book focuses on the radio frequency design and performance of antennas but covers environmental and mechanical considerations as well There is additionally a thorough treatment of all the analytical and measurement techniques used in design and performance assessment Each chapter is written by one or more leading experts in the field of antenna

technology The presentation of the history and technology of spaceborne antennas is aided by several features Photographs and drawings of JPL spacecraft Illustrations to help readers visualize concepts and designs Tables highlighting and comparing the performance of the antennas Bibliographies at the end of each chapter leading to a variety of primary and secondary source material This book complements Large Antennas of the Deep Space Network Wiley 2002 which surveys the ground antennas covered in support of spacecraft Together these two books completely cover all JPL antenna technology in keeping with the JPL Deep Space Communications and Navigation Series mission to capture and present the many innovations in deep space telecommunications

This book is a fascinating and informative read for all individuals working in or interested in deep space telecommunications

*Position, Navigation, and Timing Technologies in the 21st Century* Y. Jade Morton, Frank van Diggelen, James J. Spilker, Jr., Bradford W. Parkinson, Sherman Lo, Grace Gao, 2021-01-13 Covers the latest developments in PNT technologies including integrated satellite navigation sensor systems and civil applications Featuring sixty four chapters that are divided into six parts this two volume work provides comprehensive coverage of the state of the art in satellite based position navigation and timing PNT technologies and civilian applications It also examines alternative navigation technologies based on other signals of opportunity and sensors and offers a comprehensive treatment on integrated PNT systems for consumer and commercial applications

Volume 1 of Position Navigation and Timing Technologies in the 21st Century Integrated Satellite Navigation Sensor Systems and Civil Applications contains three parts and focuses on the satellite navigation systems technologies and engineering and scientific applications It starts with a historical perspective of GPS development and other related PNT development Current global and regional navigation satellite systems GNSS and RNSS their inter operability signal quality monitoring satellite orbit and time synchronization and ground and satellite based augmentation systems are examined Recent progresses in satellite navigation receiver technologies and challenges for operations in multipath rich urban environment in handling spoofing and interference and in ensuring PNT integrity are addressed A section on satellite navigation for engineering and scientific applications finishes off the volume

Volume 2 of Position Navigation and Timing Technologies in the 21st Century Integrated Satellite Navigation Sensor Systems and Civil Applications consists of three parts and addresses PNT using alternative signals and sensors and integrated PNT technologies for consumer and commercial applications It looks at PNT using various radio signals of opportunity atomic clock optical laser magnetic field celestial MEMS and inertial sensors as well as the concept of navigation from Low Earth Orbiting LEO satellites GNSS INS integration neuroscience of navigation and animal navigation are also covered The volume finishes off with a collection of work on contemporary PNT applications such as survey and mobile mapping precision agriculture wearable systems automated driving train control commercial unmanned aircraft systems aviation and navigation in the unique Arctic environment In addition this text Serves as a complete reference and handbook for professionals and students interested in the broad range of PNT subjects Includes chapters that focus on

the latest developments in GNSS and other navigation sensors techniques and applications Illustrates interconnecting relationships between various types of technologies in order to assure more protected tough and accurate PNT Position Navigation and Timing Technologies in the 21st Century Integrated Satellite Navigation Sensor Systems and Civil Applications will appeal to all industry professionals researchers and academics involved with the science engineering and applications of position navigation and timing technologies pnt21book com China Satellite Navigation Conference (CSNC) 2012 Proceedings Jiadong Sun,Jingnan Liu,Yuanxi Yang,Shiwei Fan,2012-04-02 Proceedings of the 3rd China Satellite Navigation Conference CSNC2012 presents selected research papers from CSNC2012 held on 15 19 May in Guanzhou China These papers discuss the technologies and applications of the Global Navigation Satellite System GNSS and the latest progress made in the China BeiDou system especially They are divided into 9 topics to match the corresponding sessions in CSNC2012 which broadly covered key topics in GNSS Readers can learn about the BeiDou system and keep abreast of the latest advances in GNSS techniques and applications SUN Jiadong is the Chief Designer of the Compass BeiDou system and the Academician of Chinese Academy of Sciences LIU Jingnan is a professor at Wuhan University and the Academician of Chinese Academy of Engineering YANG Yuanxi is a professor at China National Administration of GNSS and Applications and the Academician of Chinese Academy of Sciences FAN Shiwei is a researcher on satellite navigation

**Deep Space Communications** Jim Taylor,2016-08-16 DEEP SPACE COMMUNICATIONS A COLLECTION OF SOME OF THE JET PROPULSION LABORATORY S SPACE MISSIONS SELECTED TO REPRESENT THE PLANETARY COMMUNICATIONS DESIGNS FOR A PROGRESSION OF VARIOUS TYPES OF MISSIONS The text uses a case study approach to show the communications link performance resulting from the planetary communications design developed by the Jet Propulsion Laboratory JPL This is accomplished through the description of the design and performance of six representative planetary missions These six cases illustrate progression through time of the communications system s capabilities and performance from 1970s technology to the most recent missions The six missions discussed in this book span the Voyager for fly bys in the 1970s Galileo for orbiters in the 1980s Deep Space 1 for the 1990s Mars Reconnaissance Orbiter MRO for planetary orbiters Mars Exploration Rover MER for planetary rovers in the 2000s and the MSL rover in the 2010s Deep Space Communications Provides an overview of the Deep Space Network and its capabilities Examines case studies to illustrate the progression of system design and performance from mission to mission and provides a broad overview of the mission systems described Discusses actual flight mission telecommunications performance of each system Deep Space Communications serves as a reference for scientists and engineers interested in communications systems for deep space telecommunications link analysis and design control Antenna Arraying Techniques in the Deep Space Network David H. Rogstad,Alexander Mileant,Timothy T. Pham,2003 An introduction to antenna Arraying in the Deep Space network Antenna arraying is the combining of the output from several antennas in order to improve the signal to noise ratio

SNR of the received signal Now implemented at the Goldstone Complex and other Deep Space Network DSN overseas facilities antenna arraying provides flexible use of multiple antennas to increase data rates and has enabled NASA's DSN to extend the missions of some spacecraft beyond their planned lifetimes Antenna Arraying Techniques in the Deep Space Network introduces the development and use of antenna arraying as it is implemented in the DSN Drawing on the work of scientists at JPL this timely volume summarizes the development of antenna arraying and its historical background describes key concepts and techniques analyzes and compares several methods of arraying discusses several correlation techniques used for obtaining the combined weights presents the results of several arraying experiments and suggests directions for future work An important contribution to the scientific literature Antenna Arraying Techniques in the Deep Space Network Was commissioned by the JPL Deep Space Communications and Navigation Systems DESCANSO Center of Excellence Highlights many NASA funded technical contributions pertaining to deep space communications systems Is a part of the prestigious JPL Deep Space Communications and Navigation Series The Deep Space Communications and Navigation Series is authored by scientists and engineers with extensive experience in astronautics communications and related fields It lays the foundation for innovation in the areas of deep space navigation and communications by disseminating state of the art knowledge in key technologies

Autonomous Software-Defined Radio Receivers for Deep Space Applications Jon Hamkins, Marvin K. Simon, 2006-12-13 This book introduces the reader to the concept of an autonomous software defined radio SDR receiver Each distinct aspect of the design of the receiver is treated in a separate chapter written by one or more leading innovators in the field Chapters begin with a problem statement and then offer a full mathematical derivation of an appropriate solution a decision metric or loop structure as appropriate and performance results

**Deep Space Craft** Dave Doody, 2010-04-03 Deep Space Craft opens the door to interplanetary flight It looks at this world from the vantage point of real operations on a specific mission and follows a natural trail from the day to day working of this particular spacecraft through the functioning of all spacecraft to the collaboration of the various disciplines to produce the results for which a spacecraft is designed These results are of course mostly of a scientific nature although a small number of interplanetary missions are also flown primarily to test and prove new engineering techniques The author shows how in order to make sense of all the scientific data coming back to Earth the need for experiments and instrumentation arises and follows the design and construction of the instruments through to their placement and testing on a spacecraft prior to launch Examples are given of the interaction between an instrument's science team and the mission's flight team to plan and specify observations gather and analyze data in flight and finally present the results and discoveries to the scientific community This highly focused insider's guide to interplanetary space exploration uses many examples of previous and current endeavors It will enable the reader to research almost any topic related to spacecraft and to seek the latest scientific findings the newest emerging technologies or the current status of a favorite flight In order to provide easy paths from the general to the specific



the text constantly refers to the Appendices Within the main text the intent is general familiarization and categorization of spacecraft and instruments at a high level to provide a mental framework to place in context and understand any spacecraft and any instrument encountered in the reader's experience Appendix A gives illustrated descriptions of many interplanetary spacecraft some earth orbiters and ground facilities to reinforce the classification framework Appendix B contains illustrated detailed descriptions of a dozen scientific instruments including some ground breaking engineering appliances that have either already been in operation or are poised for flight Each instrument's range of sensitivity in wavelengths of light etc and its physical principle's of operation is described Appendix C has a few annotated illustrations to clarify the nomenclature of regions and structures in the solar system and the planets ring systems and places the solar system in context with the local interstellar environment

**Bandwidth-Efficient Digital Modulation with Application to Deep Space**

**Communications** Marvin K. Simon, 2005-02-18 An important look at bandwidth efficient modulations with applications to today's Space program Based on research and results obtained at the California Institute of Technology's Jet Propulsion Laboratory this timely book defines describes and then delineates the performance power and bandwidth of digital communication systems that incorporate a wide variety of bandwidth efficient modulations appropriate for the design and implementation of space communications systems The author compares the performance of these systems in the presence of a number of practical non ideal transmitter and receiver characteristics such as modulator and phase imbalance imperfect carrier synchronization and transmitter nonlinearity Although the material focuses on the deep space applications developed at the Jet Propulsion Laboratory the presentation is sufficiently broad as to be applicable to a host of other applications dealing with RF communications An important contribution to the scientific literature Bandwidth Efficient Digital Modulation with Application to Deep Space Communications was commissioned by the JPL Deep Space Communications and Navigation System Center of Excellence highlights many NASA funded technical contributions pertaining to deep space communications systems is a part of the prestigious Deep Space Communications and Navigation Series The Deep Space Communications and Navigation Series is authored by scientists and engineers with extensive experience in astronautics communications and related fields It lays the foundation for innovation in the areas of deep space navigation and communications by disseminating state of the art knowledge in key technologies

*Research and Technology Objectives and Plans Summary (RTOPS)*, 1985

**Modeling and Optimization in Space Engineering** Giorgio Fasano, János D. Pintér, 2023-04-29 This volume consists of 14 contributed chapters written by leading experts offering in depth discussions of the mathematical modeling and algorithmic aspects for tackling a range of space engineering applications This book will be of interest to researchers and practitioners working in the field of space engineering Since it offers an in depth exposition of the mathematical modelling algorithmic and numerical solution aspects of the topics covered the book will also be useful to aerospace engineering graduates and post graduate students who wish to expand their knowledge by studying real world applications

and challenges that they will encounter in their profession Readers will obtain a broad overview of some of the most challenging space engineering operational scenarios of today and tomorrow this will be useful for managers in the aerospace field as well as in other industrial sectors The contributed chapters are mainly focused on space engineering practice Researchers and practitioners in mathematical systems modelling operations research optimization and optimal control will also benefit from the case studies presented in this book The model development and optimization approaches discussed can be extended towards other application areas that are not directly related to space engineering Therefore the book can be a useful reference to assist in the development of new modelling and optimization applications

*Low-Energy Lunar Trajectory Design* Jeffrey S. Parker, Rodney L. Anderson, 2014-06-25 Based on years of research conducted at the NASA Jet Propulsion Laboratory Low Energy Lunar Trajectory Design provides high level information to mission managers and detailed information to mission designers about low energy transfers between Earth and the moon The book answers high level questions about the availability and performance of such transfers in any given month and year Low energy lunar transfers are compared with various other types of transfers and placed within the context of historical missions Using this book designers may reconstruct any transfer described therein as well as design similar transfers with particular design parameters An Appendix Locating the Lagrange Points and a useful list of terms and constants completes this technical reference Surveys thousands of possible trajectories that may be used to transfer spacecraft between Earth and the moon including transfers to lunar libration orbits low lunar orbits and the lunar surface Provides information about the methods models and tools used to design low energy lunar transfers Includes discussion about the variations of these transfers from one month to the next and the important operational aspects of implementing a low energy lunar transfer Additional discussions address navigation station keeping and spacecraft systems issues

Formulation for Observed and Computed Values of Deep Space Network Data Types for Navigation Theodore D. Moyer, 2003-01-31 A valuable reference for students and professionals in the field of deep space navigation Drawing on fundamental principles and practices developed during decades of deep space exploration at the California Institute of Technology s Jet Propulsion Laboratory JPL this book documents the formation of program Regres of JPL s Orbit Determination Program ODP Program Regres calculates the computed values of observed quantities e g Doppler and range observables obtained at the tracking stations of the Deep Space Network and also calculates media corrections for the computed values of the observable and partial derivatives of the computed values of the observables with respect to the solve for parameter vector  $q$  The ODP or any other program which uses its formulation can be used to navigate a spacecraft anywhere in the solar system A publication of the JPL Deep Space Communications and Navigation System Center of Excellence DESCANSO Formulation for Observed and Computed Values of Deep Space Network Data Types for Navigation is an invaluable resource for graduate students of celestial mechanics or astrodynamics because it features the expertise of today s top scientists places the entire program Regres formulation in an

easy to access resource describes technology which will be used in the next generation of navigation software currently under development The Deep Space Communications and Navigation Series is authored by scientists and engineers with extensive experience in astronautics communications and related fields It lays the foundation for innovation in the areas of deep space navigation and communications by conveying state of the art knowledge in key technologies

## **Radiometric Tracking Techniques For Deep Space Navigation** Book Review: Unveiling the Power of Words

In a world driven by information and connectivity, the power of words has become more evident than ever. They have the ability to inspire, provoke, and ignite change. Such may be the essence of the book **Radiometric Tracking Techniques For Deep Space Navigation**, a literary masterpiece that delves deep into the significance of words and their effect on our lives. Compiled by a renowned author, this captivating work takes readers on a transformative journey, unraveling the secrets and potential behind every word. In this review, we will explore the book's key themes, examine its writing style, and analyze its overall effect on readers.

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### **Radiometric Tracking Techniques For Deep Space Navigation Introduction**

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