

Preface

The Jet Propulsion Laboratory (JPL) is an operating division of the California Institute of Technology (Caltech) in Pasadena, California. JPL's history started in the early 1930s when a graduate student in Caltech's Guggenheim Aeronautical Laboratory, Frank Malina, made a proposal to his professor, Theodore von Karman, for a topic for his thesis. The proposal was to design, build, and test a rocket motor. His proposal was accepted, and Malina started work. He quickly picked up two assistants, and together they made good progress, so good in fact that they were forbidden from any further experiments (and the associated noise) at Caltech. They moved their equipment to a dry arroyo, just outside the Pasadena city limits, about 12 km from the Caltech campus, in what is now the city of La Cañada. This is the present site of JPL.

Successful experiments continued throughout the 1930s, and by the start of the second World War, von Karman had set up the work as a new laboratory that later was called the Jet Propulsion Laboratory. JPL's experiments were successful and picked up U.S. Army funding, which continued throughout World War II and beyond. At this time ballistic missiles were under development, and JPL was also involved with radio tracking and control of the missiles. This tracking system was the forerunner of the present worldwide Deep Space Network (DSN) for tracking spacecraft.

In 1957, the Soviet Union startled the world by launching Sputnik, the first artificial satellite. The following year, JPL became part of the newly formed National Aeronautics and Space Administration. Since then, JPL and its DSN have been leading or supporting exploration of every planet in the Solar System and many other astronomical bodies.

One of today's objectives of JPL is to further our understanding of the origin and evolution of the Solar System, and the origin and evolution of life in the Universe. This is undertaken by robotic spacecraft missions to the planets,

their moons, the asteroids, and the comets. In addition, JPL supports spaceborne observatories probing the limits of the Universe. Furthermore, the probes for this exploration are yielding data at steadily increasing data rates. The DSN's objectives, therefore, are to acquire telemetry data from spacecraft, transmit commands to spacecraft, track spacecraft position and velocity, perform very-long-baseline interferometry observations, conduct radio and radar astronomy, measure variations in radio waves for radio science experiments, gather science data, and monitor and control the performance of the network.

The DESCANSO books-series editor, Joseph H. Yuen, provides a definition and description of the technology of the DSN. This book is one in this series and describes the low-noise microwave systems that form the front end of all the DSN ground stations. The microwave front end is key to establishing the sensitivity and capability of the receiving chain, and therefore, of the entire ground station. The receiving system sensitivity and capability are defined by G/T where G is the antenna gain and T is the overall noise temperature of the entire receiving chain, usually called system operating noise temperature, T_{op} . To improve the station's receiving capability, it is necessary to improve G/T . This can be done by increasing antenna gain or by decreasing T_{op} . In the past the DSN has both increased G and reduced T_{op} . It has been somewhat more cost effective and efficient to decrease T_{op} than it has been to increase G .

As the microwave front end of the station is crucial to establishing the sensitivity and capability of the receiving chain, it is therefore incumbent on the designers of the receiving system to expend considerable effort in reducing T_{op} and in calibrating and maintaining the low-noise front end. The more accurately T_{op} can be defined, the narrower the tolerances on the design of a spacecraft mission that can be accepted. This reduction in a project's design tolerances on spacecraft power can yield a considerable reduction in cost, it can enable an increase in the science data rate for the same spacecraft power, or it can provide some compromise between the two. Hence, improving calibration accuracy of the receiving chain is vitally important. Accurate noise-temperature calibrations are also necessary for the maintenance of the low-noise performance of the station. In a similar manner, the accuracy in the measurement of antenna gain is also important. This book also describes current antenna calibrations, some of which are new.

The challenge of successful radio communication at planetary distances is unique and challenging. An extremely low-noise front end is a requirement for the sensitivity that must be, and is, routinely achieved within the DSN. This book is a description of the various low-noise systems in the DSN; their development, calibration, and operation; and how these systems have been used

for tracking and for science. Overall system noise-temperature calibration of the front end is considered in one chapter, and important types of low-noise receiver front end are treated in detail in other chapters, as is the atmosphere and the calibration of antenna gain.

The book will be useful to designers and operators of communications systems, radio- and radar-astronomy stations, space-research facilities, and interferometry observatories. Analyses are presented in detail with rigor, and key equations are summarized for easy reference. The use of precise definitions (more precise than usually used in industry) in system noise temperature calculations is unusual. These definitions are based on IEEE standards and definitions not always used by practitioners. No other book goes into this level of detail. However, all analyses and equations are explained in full with examples from field measurements. The detailed explanations mean that limited engineering knowledge is sufficient to understand the text, but the rigor is there if required. High school algebra and undergraduate level calculus are generally sufficient to understand this book, although some parts may require graduate level calculus. However, the analyses are given with examples and working programs in detail so that no calculations or mathematics are required for the statistics and averages of calibration errors of measurements.

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