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Rongjun Shen
Weiping Qian *Editors*

第26届中国飞行器测控学术会议论文集

共享灵活的测控系统

Proceedings of the 26th Conference of Spacecraft TT&C Technology in China

Shared and Flexible TT&C (Tracking, Telemetry and Command) Systems

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内 容 简 介

本书精选并收录了第 26 届中国飞行器测控学术会议的优秀论文 42 篇。内容覆盖了测控总体技术、测量与控制技术、信息传输与处理技术、弹道轨道与导航技术等 4 个方面，反映了我国航天测控领域的最新科研进展。本书可供相关领域的研究人员以及工程技术人员阅读参考。

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Preface

The start of the twenty-first century has seen rapid development of China's space endeavors. Breakthroughs have come one after another from manned spaceflight missions and lunar exploration missions. The first-generation Chinese tracking and data relay satellite system is already operational and a full constellation Compass/Beidou navigation satellite system will soon be in place. Very productive space applications have been developed for ocean environment and earth resource monitoring, communications, and meteorology. Even more exciting milestones are yet to come as the momentum builds in these and other rising fields in the near future. China's space station will soon be launched and will soon send a rover to land on the moon and return to the Earth. China will also send a probe to explore Mars.

The rapid development of China's space capabilities has included successful development of Tracking, Telemetry and Command (TT&C), and communication systems to meet unprecedented opportunities and challenges. As a result of the persevering efforts of generations of scientists, China already has TT&C and communication systems that encompass land-based ground stations, seagoing instrumentation ships, instrumentation aircraft and tracking, and data relay satellites. The system has the capability to provide a wide range of support to all types of spacecraft at all altitudes of earth's orbit. China's deep space TT&C network successfully provided support to its Chang'E-1 and Chang'E-2 lunar exploration missions and significant growth of the network is expected in the near future. However, there are still numerous issues needing in-depth studies in China's TT&C system. For example, interconnectivity between TT&C networks and the integrated utilization of resources needs further development, inter-department and inter-mission coordination is too complicated and more synergy is needed in the development of ground systems.

With "Shared and Flexible TT&C Systems" as its theme, the 26th Conference of Spacecraft TT&C Technology in China highlights the latest developments related to standardization, informatization, networking and intelligent technologies, and their applications in the field of aerospace TT&C. The objective is to promote the development of an interconnectivity-oriented, resource-sharing, responsive, flexible, and efficient TT&C system with state-of-the-art technologies based on the specific needs in China. Only in this way is it possible for us to assure healthy long-term development of our TT&C system and to meet the future requirements of China's space program.

The conference, which is organized by the Spacecraft TT&C Committee of the Chinese Society of Astronautics, received more than 250 papers from experts nation-wide with 42 selected for publication. I firmly believe that publication of the proceedings of this important conference will promote international exchange and provide a new channel for sharing of the latest research achievements and engineering practices in the field of spacecraft TT&C.

October 2012 Rongjun Shen

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Part I
Spacecraft TT&C System Design and Research

Chapter 1
Space-Based MA TT&C System and Technologies

Jianping Hu, Hongjun Yang and Maoge Xu

Abstract Multiple Access (MA) service provided by Tracking and Data Relay Satellite System (TDRSS) is a space based MA TT&C and communication service using satellite relay. Spaced-based MA TT&C system is specialized in the implementation and application. In this paper the performance and technology development of S-band MA service provided by TDRSS is analyzed. As a feature of TDRSS SMA services, the major difference from that of conventional communication satellite is that its MA assignment has to be relayed and managed by ground station. Key technologies related to space based MA TT&C and communication are determined and their implementation solutions are proposed.

Keywords Space-based MA TT&C and communication · Data relay satellite · MA access · Adaptive beam forming · Demand access · Calibration

1.1 Introduction

As a typical space based TT&C and communication system, data relay satellite system is able to provide user with tracking and data relay capabilities. Its Ku/Ka-band inter-satellite link is used for high rate data transmission, and its S-band single access (SSA) and S-band multiple access (SMA) services are used for command, telemetry, data transmission and ranging. With onboard phased array, SMA Service provides a communication path from customer platform via a geosynchronous data relay satellite to a customer control centre.

J. Hu (✉) · H. Yang · M. Xu
Southwest China Institute of Electronic Technology, Chengdu 610036, China
e-mail: jphu63@sina.com

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MA system of data relay satellite is a MA TT&C and communication system using space multi-beam and code division multiple target via satellite relay [1, 2]. An obvious difference from common MA communication satellite is that its MA service is relayed and managed by ground system, through which the communication and TT&C services between user platform and user centre can be realized. The space link involves on-board multi-beam and space-ground MA, resulted in special system implementation and application. The corresponding key technologies shall be studied and implemented in system design [3, 4].

1.2 Development of Space-Based MA TT&C and Communication Technology

Space Network (SN) concept is proposed firstly by NASA. Now its TDRSS system is established and consists of two generations of nine satellites and three ground stations. No Zone of Exclusion (ZOE) exists in the coverage provided by current TDRSS constellation, and 100 % orbit coverage is provided for user spacecrafts at 200 km altitude. The data relay satellites from ESA and NASDA provide only data relay capability without MA communication service. Space-based MA communication technology was used in the first and second generation of TDRSS [5]. In its third generation satellite system design, ground multi-beam forming, which was utilized in the first generation, is also used to enhance communication security.

In development of two generations of TDRSS satellite system, in addition to advanced technologies, its application range is expanded to include various users, including spacecrafts in LEO and MEO, South Pole science survey team, rocket, Long Duration Balloon Platform (LDBP) and so on.

The third generation satellite is designed based on second generation satellite with following differences: (1) SMA return beam is formed on ground, and (2) onboard command and telemetry link communication security (COMSEC) system is upgraded.

For user access, conventional pre-assignment mode was used in TDRSS initially. It can provide satisfied service for large spacecraft, but can not provide rapid and flexible automatic service for other spacecrafts such as small satellite because of high occupation cost on system equipment, prepare time and human resource. So in order to enhance customer MA access capability and increase customer number, Demand Access System (DAS) was used in ground station in 2004 to provide non-schedule MA return link service. With DAS, any number of beamformer can be incorporated in ground station, which is only limited by the number of available receiver/demodulator.

The Demand Access System will provide services by adding global system control, coordination functions, and data distribution capabilities into the ground systems. For the new services enabled by DAS, the DAS will [2, 6]:

1. Provide the capability for continuous, conflict-free, DAS MA return link services 24 h per day, 7 days per week upon demand from customers.
2. Provide an automated capability to transition DAS customer services between TDRSs/Space Ground Link Terminals (SGLT).
3. Provide the capability to support multiple, independent MA return links per TDRS/SGLT/ground station.
4. Meet or exceed the current communications performance and capabilities of the existing MA return link with the exceptions of the functions not possible due to the lack of tie-ins with the MA forward link.
5. Provide demodulation and data distribution capabilities for each DAS MA return data service.
6. Automate the operation of all DAS return link services.
7. Provide COTS data and control interfaces for DAS customers with the flexibility of accommodating non-standard/customer-unique telemetry interfaces.
8. Provide simple, low cost, modular expansion capabilities to facilitate the addition of DAS return link channels, as needs change.

With a new demand access capability, many customers will have low cost access to the SN. The new demand access capability is ideal for spacecraft flying in formation, which have relatively low data rate requirements or single spacecraft and other non-orbital vehicles that need a continuous communications link. Meanwhile, the adaptive ground-based multi-beamforming provides the system with flexible, stable, reliable, safety, expandable space access capability, and support DAS realization.

1.3 Key Techniques for Space-Based SMA TT&C and Communication

Space-based MA service is a special satellite MA communication system compared with common satellite communication system. Its MA access, customer management, FDM, and beamforming, calibration, and control of multi-beam antenna are precondition and guarantee to realize optimal communication performance. All key technical challenges shall be well resolved.

Refer to NASA's SMA designs and future plans from first to third generations of TDRSS, following development are observed:

1. Phased array antenna, which is used to implement Code Division + Space Division MA communication in space–space link.
2. FDM or Double DSSS, which is used in space-ground link for transmission of CDMA signals transmitted/received by elements in phased array.
3. Adaptive ground multi-beamforming, which can provide better adaptability to various customers and higher anti-jamming capability.

4. Multiple customer management and data relay, which is performed in ground station to enable DAS and provide better expandability.

This multiple channel MA communication is more complex than single channel communication and conventional MA satellite communication. Following technical challenges must be resolved.

1.3.1 Application and Management Mechanism for MA Communication

The application and management of MA communication is critical for ground operation control system, which is a key point for system normal operation. Space based SMA communication management using DAS is an effective method for application and improving of system capability.

Customers will realize many technical and logistical benefits from the implementation of DAS. Examples of benefits could include:

1. Immediate access to services in support of science and spacecraft safety.
2. Reasonable system resource configuration. A DAS return link could be configured to poll several different spacecraft automatically to reduce channel idleness and increase system availability.
3. Extended duration services without service interruption, which can improve operation flexibility and autonomy for customer vehicle.
4. Simplified scheduling and operation which can improve system automation and unattended monitoring levels.
5. Simplified expansion when service loading increases through the modular nature of DAS.

To establish DAS system, data flow and service flow with reasonable system configuration is core. Demand access system equipment configuration and data flow is shown in Fig. 1.1. Central management can be utilized for DAS equipment. IF signals from de-multiplex channels of several ground stations in same location are sent to given processor in expandable beamformer group via data distribution equipment for beamforming. The DAS equipment in ground station at different area can send data to central station DASCON via data transmission network to implement central control and management.

Schedule, initiating, and monitoring of DAS service are all performed automatically by DASCON, i.e. beamforming, demodulation, and return data distribution are all managed automatically based on DAS customer resource configuration requirements without operator intervention so as to real-time support space mission and ground emergency service.

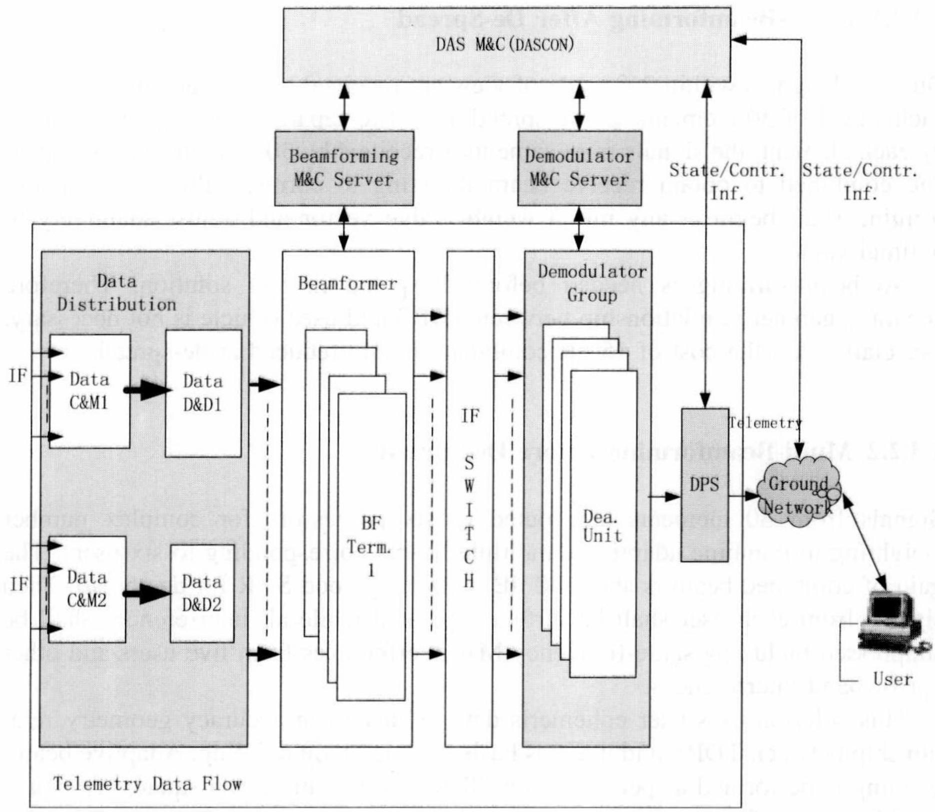

Fig. 1.1 Schematic diagram of space based MA communication DAS components and data flow. *M&C* Monitor and Control, *C&M* Copy and Multiplexing, *D&D* Demultiplexing and Distribution, *Term.* Terminal, *Demo.* Demodulator, *DPS* Data Processing Server

1.3.2 MA Access Methods

Time division multi-beam controlled by ground station is utilized in forward link meanwhile a forward link to customer is established.

Multi-beamforming is performed on ground at the same time for return link, which is key for multi-beamforming and customer access. SCDMA and CDMA are used to access multiple customers, which is a new technology for TT&C. So there is a challenge to select a proper MA access for special TT&C application. By comprehensive analysis, there are two options for SDMA and CDMA scheme of SMA return link [6, 7].