Key Considerations for Communication Satellite System Design

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Abstract — This paper is an introduction for communication satellite constellation, which is currently being studied by KAI(Korea Aerospace Industries, LTD) as a preliminary model. The main purpose is to explore operation concept, core design and manufacturing technologies.

Keywords— Communication Satellite, Inter-Satellite Link, Additive Manufacturing, Electrical Propulsion System

I. INTRODUCTION

Conventional satellite communication has been limited to services such as broadcasting or single communication due to limitations in cost and technical complexity. However, with recent technological breakthroughs in satellite launch and manufacturing sectors in the new space era, usability of satellite communication has been expanded to space Internet and network services. As a representative example, Space X launched Starlink system, space Internet service satellite constellation. It provides Internet service to regions around the world, and more than 10,000 Starlink satellites are scheduled to operate. Number of other companies including KAI are also conducting research on communication satellite and the development of communication satellite system is planned for civilian and military in South Korea. In this study, the operating concept of communication satellite constellation and the core design/manufacturing technologies are described in satellite system.

II. CONSTELLATION CONCEPT

In the development of communication satellites, efficient orbital design and operational concepts are essential in system preliminary design. Communication satellites can be operated in all earth orbit including LEO, MEO, GEO and each earth orbit has its own pros and cons. Therefore, it is necessary to establish a design concept in consideration of the service purpose, performance, target area, etc.[1].

< Low Earth Orbit, LEO >

LEO communication service is essential for autonomous flight technologies such as UAVs and drones because of its short communication latency due to low altitude. However, since the coverage of individual satellites is not wide compared to that of other orbits, a relatively large number of satellites are required. Therefore, a satellite constellation is required to provide continuous service to users. In the construction of LEO satellite constellation, it is more economically efficient to provide global services than local services due to the orbital characteristics.

< Medium Earth Orbit, MEO >

MEO is typically used for navigation, but it is being considered as an alternative orbit for communication satellites due to LEO overcrowding and GEO saturation. Compared to LEO, MEO has less frequency interference and wide coverage, which enable cost-effective global service implementation. In addition, in densely populated areas, high-performance services can be provided when MEO and HEO(highly elliptical orbit) are jointly operated.

< Geostationary Earth Orbit, GEO >

GEO orbital speed is the same as the Earth's rotation speed, so it is possible to provide stable service by being located in a fixed area. Since HTS(high throughput satellite) are required for long-term broadband service at GEO altitude, satellites have high mass, power, and reliability requirements. GEO has a longer latency than LEO, but since it provides broadband services, it can be used for disaster response and the Internet for aircrafts and ships.

< Multi-orbit Combination>

Designing an operating concept that combines different trajectories can provide a more flexible service. When LEO and GEO are operated together, global services can be provided through LEO satellites and high-performance services can be provided in densely populated areas through GEO satellites. However, network connection between different orbits for stable service is technologically demanding in managing handover due to different orbital speeds.

III. CORE DESIGN TECHNOLOGY

As a new paradigm of communication service in which integrated terrestrial and satellite networks is proposed, functions of the satellite which is flexible, light in mass and constellation are required. In this section, we identified and analyzed the main technologies to implement these required functions.

< Flexibility >

Existing analog repeater in the satellite basically has performed the role of relaying signals for each link. SD(software defined) digital repeater, in addition to performing the same functions as analog repeaters, refers to a software mounted digital repeater that enables the software to be changed on the ground in preparation for satellite communication standards change. This technology is said to have an advantage in securing price competitiveness of communication satellites in the future because it can be coped with changes flexibly in communication standards. Recently, the role of SD digital repeater has been expanded to include the ability of the network management that combines the phased array antenna and OBC (on board computer) to form the optimal beam and allocate resources according to the user's demand as shown in Figure 1.

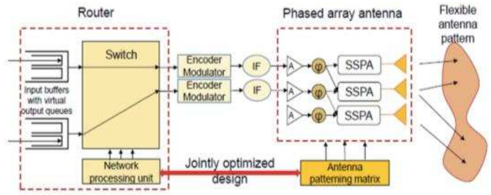

Fig. 1. The structure of the digital repeater incorporating the optimal beam allocation[2]

< Mass Reduction >

In the current satellite system, it is required for satellites to have self-propellant system in order to get to mission orbit or maintaining attitude. Conventionally a chemical propulsion system is used, and the amount of the propellant accounts for a high proportion of the total mass of the satellite. The electric propulsion system is developed to overcome the mass disadvantages of the chemical propulsion system. Unlike chemical propulsion system that uses chemical reaction energy of a propellant, the electric propulsion system supplies energy to the propellant using an external power supply device. This can reduce the size and mass of satellite by reducing propellant amount, ultimately reducing launch cost and securing the capacity for simultaneous launch, or adding more communication payloads.

However, electrical propulsion system has mass advantage over chemical propulsion system, thrust that the thruster can generate is low. Therefore, in applying the electric propulsion system, the maneuvering time according to the thruster, and the amount of electric power should be considered according to the mission and orbit of each satellite.

< Constellation >

ISL(inter-satellite link) is refer to mutual observation system between satellite to measure relative distance and velocity or to send/receive data through communication. ISL measures the relative distance between satellites and improves the accuracy in determining the orbit and attitude, so it is mainly used for the operation of constellation satellite. Because of this advantage, constellation management without the intervention of the ground station during formation flying is possible.

By utilizing the interconnection between satellites, ISL can monitor the status information of satellite in real time without restrictions of ground station location, and the communication time between the ground station and satellite. In addition, since it is possible to transmit commands and missions at all times, the efficiency of satellite operation can be increased.

IV. Constellation Construction Technology

In order for communication satellite system to provide stable Internet service worldwide, large number of satellites need to be launched to space during the initial constellation construction phase and continuous launch of replacement satellites is required for upkeeping of the constellation. Therefore, in terms of satellite manufacturing, innovative manufacturing technologies such as additive manufacturing and automated production are being implemented. Additionally, in terms of satellite launch, major technological considerations include dispenser technology for simultaneous launch of satellites.

< Additive Manufacturing Technology >

Additive manufacturing technology is a processing method in which three dimensional objects are fabricated by stacking resin or metal in liquid or powder state in a layer-by-layer manner. With the application of additive manufacturing, the overall satellite manufacturing time can be significantly reduced as the fabrication time of each part are short in comparison to conventional subtractive manufacturing, some assembly processes are no longer needed as assemblies can be fabricated as a single part. Furthermore, additive manufacturing can contribute to satellite mass reduction, consequently reducing launch cost. Since geometrically complex parts can be fabricated using additive manufacturing, satellite manufacturers can now produce lighters parts designed with topology optimization method. Additive manufacturing technology is being employed by Fleet Space and Iridium for their communication satellite constellation.

< Automated Production Technology >

Automated production technology refers to production process in which robots are used to automatically perform specific manufacturing process. Replacing some labor-intensive processes in satellite mass production process with automated production can improve production efficiency and assure uniform quality. A representative example of applying automated production the satellite production process is Oneweb satellite production facility, which is a joint venture between Oneweb and Airbus. With automated solar cell laydown and potting processes, Oneweb is building maximum of 2 satellite per day to meet their launch schedule.

< Launch dispenser technology >

Launch dispenser refers to a mechanism that hosts multiple satellites for multi-satellite launch. Utilization of dispenser system can reduce the launch cost and constellation construction time as it allows for the launch of multiple satellites. Currently, most communication satellite companies such as SpaceX, Oneweb, and Orbcomm use launch dispenser technology to build their satellite constellation[3].

V. Conclusion

With the recent technological development of satellite launch and manufacture, the demand for communication satellites that provide Internet and network services using constellation system is increasing. The essential technologies required for the development of constellation communication satellites include operational concept though constellation orbit design, satellite bus design technologies (flexibility, mass reduction, constellation), and manufacturing technologies (additive manufacturing, dispenser, etc). KAI is conducting preliminary research to secure the core technology derived from this study.

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