Total Configuration of Satellite Communication System

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In this chapter, we will describe total configuration of satellite system as a condition of development in “Term B”, which will be introduce in next section.

1 Introduction

In this paper, we describe the overall system configuration and specifications of a satellite-mounted communication system to determine the preconditions for the development of Term B) which will be described in the following sections, for the purpose of clarifying the coverage and scope of our prototype development and research and development activities. Also, we will mention the scale specification—complexity, volumes, sizes, performances, etc.,—of a full-scale system that would be installed on an actual satellite, and evaluate our prototype in comparison with it.

2 Onboard satellite communication system outline: Assumed for R&D

Figure 1 shows the block diagram of the assumed satellite-mounted system.

The satellite is distinctive in the following two points: first, it adopts a 2-hop configuration for communication, and second, it has a digital transponder system on board. In the 2-hop-configuration communication, the user-uplink communication signals in the S-band carrying communications from a mobile satellite-communication terminal, going through the satellite system, moving down through the Ku/Ka band feeder-link to a satellite-communication ground station, and reaching the other party. The signals from the other party move following the reverse path—from a ground station, through the on-board system, and downloaded to the S-band terminal. Hence, the satellite is used twice in one round-trip communication. Of course, such a configuration might be applicable where a link device (cross-link device) inserted between the on-board receiver and transmitter accomplishes the inside-satellite S-band looping-bask/feeder-link looping-back.

However, we kept such a configuration out of the scope of our study, mainly by the reason that such a configuration, S-band looping back, will make it difficult to implement billing mechanisms in commercial systems. However, from the standpoint of communications in an emergency situation, such a configuration, S-band looping back, would be worthwhile to employ. Another distinctive feature is the employment of a fully digital transponder. Signals received by the antenna elements of the satellite, amplified by a low-noise amplifier (hereinafter, referred to as LNA), converted into intermediate-frequency by a converter and digitized by an analog-to-digital (hereinafter referred to as AD) converter into digital signals, are used in the satellite for beam forming or channel allocation change—they are accomplished by full-digital processing. Then, the output of the digital transponder is converted into analog signals by a digital-to-analog (hereinafter, referred to as DA) converter, frequency-converted by a converter into a feeder-link frequency, and is fed to an amplifier such as a travelling wave tube (hereinafter, referred to as TWT). In such a way as described above, the feeder-link for the satellite is established.

Fully digital transponders including that described above have been considered to be inappropriate to mount on a satellite because they consume quite a large amount of power. However, as a result of the recent advancement in digital device miniaturization, a drastic reduction in their power consumption has become realistic, and similarly, other satellite-mounted equipment has become miniaturized. Hence, satellite-mounted digital equipment is acquiring a large capacity[1]. In addition, our digital transponder is quite distinctive in its digital beam forming (hereinafter referred to as DBF) capability—attained by a device installed on the satellite—, different from the digital transponders on other countries’ communication satellites which have no on-board beam-forming capability—their beam forming is generally accomplished on the ground[2]. Such beam forming method used in other countries, called

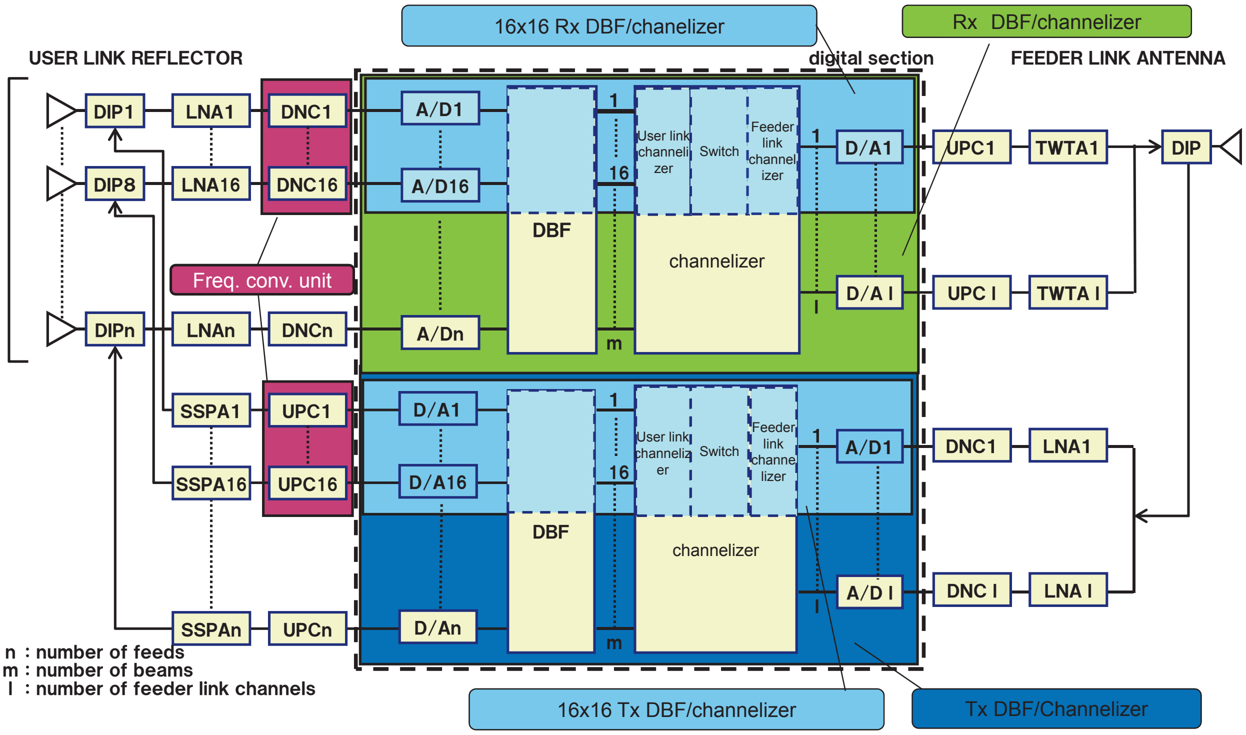

Fig. 1 Blockdiagram of satellite

“Ground Base Beam Forming” (GBBF), requires such a wide bandwidth for the feeder-link that they have to secure the bandwidth through using multiple beams for the feeder link. However, because such multiple-beam forming involves more than one ground station, the ground-system cost goes up.

Therefore, we have decided to employ an on-board DBF system.

3 Inside-satellite signal flows and prototype coverage: Outline

In this section, following the signal flows inside the satellite shown in Fig. 1, the STICS Satellite On-Board System is introduced, along with descriptions on the prototype coverage. In the left-most side of Fig. 1, the S-band reflector (Large Deployable Reflector: LDR) is shown. Signals travelling from the ground, reflected by the reflector, reach the S-band primary feed array. As for LDR, a 30-m diameter-class deployable antenna is planned under close collaboration with the large deployable reflector antenna project[3] of the Japan Aerospace Exploration Agency (hereinafter referred to as JAXA), studies on the specifications for the deployable reflector surface—JAXA designed an LDR in the research of the Engineering Test Satellite VIII-type (ETS-VIII).

The primary reflector is assumed to have up to 100 elements. In the research and development in the STICS project, we conducted proof-of-concept experiments on a feeder scale model having a close-coupling-fed patch antenna with parasitic-element and cavity[4] with 16 elements—the antenna was newly developed for the experiments. In addition, for the primary radiator of the feeder, we, proposing a parasitic-element-mounted close-cavity-coupling-fed patch antenna optimized for de-focus feeding of a 120 mm-inter-element spacing, conducted measurements for clarifying its characteristics. Furthermore, we have been studying the design or other issues that would arise when it is employed as on-board equipment[5]. The DIP shown in Fig. 1 is a diplexer; in STICS, we used its light-weight model for experiments. LNAs of an equivalent number to that of the antenna elements are to be mounted on a satellite. An LNA receives the desired waves—waves used for satellite uplink—, and at the same time, it is exposed to interference produced when the waves used for ground communications reach the satellite. So, the requirements for a satellite-onboard amplifier are that it not become saturated under relatively powerful inference and that it receives the desired waves. For fulfilling these requirements, we, starting study on an amplifier that is not saturated by interference over 20-dB more powerful than the desired wave, successfully developed an anti-saturation low-noise amplifier[6] that is not saturated under interference 40-dB more powerful than the desired wave.

Behind the LNAs, the S-band signals are converted by frequency converter units and amplified into AD input signals. Because those units are indispensable for our experiments, we prepared 16 units—equivalent to the number of antenna elements. Also, IF units, with their power supplied by the local oscillator (LO), are required to do very large-amplitude operations—as large as around +10 dBm amplitude per element; so, much care should be taken for energy consumption, when level-allocation is designed.

Behind those units just described above, digital units are working as follows: AD converters of a number equivalent to that of the elements work; for beam forming, the DBF unit with beam-forming processing capability of the scale of (the number of the elements) multiplied by (the number of beams) work. Following those, the digital channelizer conducts wave-signal-branching/composition; and the on-board channelizer gives the satellite the capability of adaptive—according to the situation—beam re-configuration functions as exclusively connecting the channel that is used for communications to the feeder-link, or selectively increasing the bandwidth of a specified beam. The input-side bandwidth per beam is, except for in special cases, determined by the frequency—30 MHz, assumed in the STICS cases—and the repetition number—seven, assumed in STICS—through the equation, frequency divided by repetition number, to be 4.2 MHz (30/7). However, in some special situations, slightly different parameters would be used for special beam-forming—for example, in a disaster situation, enlarging the bandwidth allocated for the disaster area or reducing the bandwidth allocated for the beam covering a sea area where no large communication demands are expected.

The maximum output-bandwidth of the channelizer is "per-beam bandwidth multiplied by the number of beams"; so, for the assumed frequency-repetition number of seven and the bandwidth of 30 MHz, the per-beam bandwidth is 4.2 MHz (30 divided by 7), and then, the maximum channelizer output-bandwidth is 420 MHz. Those signals, after being converted by DAs into analog signals, are connected, through the feeder link channel, to ground stations. However, it is not necessary to relay the whole bandwidth of up to 420 MHz through the feeder link. Instead, selective relaying of the channels using a channelizer is sufficient. This contributes to efficient bandwidth utilization through reduction of the feeder-link bandwidth.

If considering the actual situation where STICS is on-board, the 100-element-by-100-beam class DBF will be required. However, in the first half of our research and development, we, taking a step-by-step approach, developing a 16-element-by-16-beam class small-scale channelizer DBF system, a 16-element primary radiator, and a frequency converter unit—they match the DBF system to be developed—, conducted beam forming experiments and lowering side-lobe experiments. Furthermore, we conducted system experiments through combining our units with the proof-of-concept 3.3-m diameter satellite onboard deployable antenna that was previously developed by NICT and using the anechoic chamber of Kyoto University (A-METLAB).

In the second half of our research and development project, based on the achievements attained on the small-scale DBF channelizer, we developed the 100-beam class ultra-multi beam DBF channelizer; and in the final year of our project, we conducted integration experiments in A-METLAB through combining the ultra-multi-beam channelizer with the previously mentioned equipment—16-element primary radiator, frequency converter unit, and proof-of-concept model 3.3-m diameter satellite on-board deployable antenna, and furthermore, conducted system integration experiments using A-METLAB through combining the DBF channelizer with the network monitoring/management system developed in item a).

In this special issue, in Chapter **3-5** and **3-6**, the achievements on DBF-based beam-forming and side-lobe suppression, and in **3-7** the evaluation of transmission characteristics when DBF and channelizer are used, will be reported. Furthermore, in Chapter **4**, the combination experiments with item a) will be introduced.

4 Summary

In this paper, we have introduced, on the research and development of Term B), the assumed satellite-communication system for the STICS project and the coverage of the experiments or prototype developments conducted in the STCIS project. In the scope of the STICS project, full-scale development and verification of prototypes were not conducted. However, the STICS project proactively and successfully conducted research and development activities on the serious technical issues that will arise in actual situations. The most significant among our achievements is that we conducted in-detail verifications of the feasibility of the DBF/channelizer satellite-mounted systems of the required scale to have confidence in its feasibility.

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