Experimental study for DBF and channelizer for Satellite/Terrestrial Integrated mobile Communication System

Yoshiyuki Fujino, Hiroyuki Tsuji, Norio Komiyama, Teruaki Orikasa
National Institute of Information and Communications Technology
4-2-1 Nukui-kita, Koganei, Tokyo, Japan, Email: fujino@nict.go.jp

1. Introduction

The utility of satellite-based mobile phone systems in disaster management is well known. Since the high free-space path loss, large antennas mounted on satellite terminals are needed.
In recent years, mobile communication systems with integrated satellite/terrestrial functions have been developed to provide wide-ranging services; these systems employ a large deployable antenna in a satellite terminal along with a small terrestrial terminal.

Today, by employing a small podrtable terminal, the Thuraya Satellite Telecom Co. provides satellite communication and global system for mobile (GSM) communication in more than 100 countries across the world including countries in the Middle East, Europe, North and Central Africa, and Asia[1]. Further, SkyTerra Communications is trying to implement mobile communication systems that will improve the frequency utilization efficiency by integrating the frequencies of the terrestrial and satellite systems; they also plan to implement a communication system that will make up for the lack of the coverage of a satellite system by effectively employing a terrestrial system[2]. In the system used by SkyTerra, a satellite dish antenna having a diameter of 22 mϕ and operating in the L band is used to cover the entire North American region with hundreds of spot beams. However, the communications system design for Japan has to be significantly different because of the difference in area and population distribution.

So, we proposed a communication system that enables improvements in the frequency utilization efficiency by integrating the frequencies of the terrestrial and satellite systems. A deployable antenna having a diameter of 30 mϕ will be installed in the satellite and approximately 100 high-gain multibeams will be used to cover Japan and exclusive economic zones (EEZs)[3].

For small scale model of STICS satellite beam former and digital bentpipe system, NICT developed 16-elements 16-beams Digital Beam Former (DBF) and Channelizer of 120 MHz bandwith for flexible usage of frequency. Fundamental experiment was done in such equipments. In DBF, beam forming up to +-2.0 degress coverage which covers whole Japan island and EEZs. In channelizer, varying bandwith of each beam, we can demonstrate normal case and disaster case. In this paper, we will introduce preliminary result of this experiment in detail.

2. STICS System

Our communication system is called the satellite/terrestrial integrated mobile communication system (STICS). This system can be used to achieve “dual” communication and can be connected to both terrestrial and satellite systems; a common terminal is used for both communication. The handheld terminal is used for voice-data communication with a micro satellite antenna, and a portable terminal is used for data communication with a small satellite antenna.

The earth station and the base station are both equipped with a controller. They can be simultaneously managed using the common controller via a core network. Moreover, it can be used to connect to the public switched telephone network (PSTN) as well as the internet through the core network (Figure 1).

In this system, frequency is assumed between 1980–2010 MHz (uplink) and 2170–2200 MHz (downlink), which is in accordance with the allocation by Mobile Satellite System (MSS) in International Mobile Telecommunications-2000 (IMT-2000).

To achieve such system, high EIRP and G/T communication satellite is needed by using multibeam antenna with the reflector in 30mϕ class. Specifications of the satellite number of beams, antenna gain and G/T are 100 beams, more than 47dBi and more than 21dB/K, respectively. Figure 2 shows the conceptual figure of the STICS Satellite.

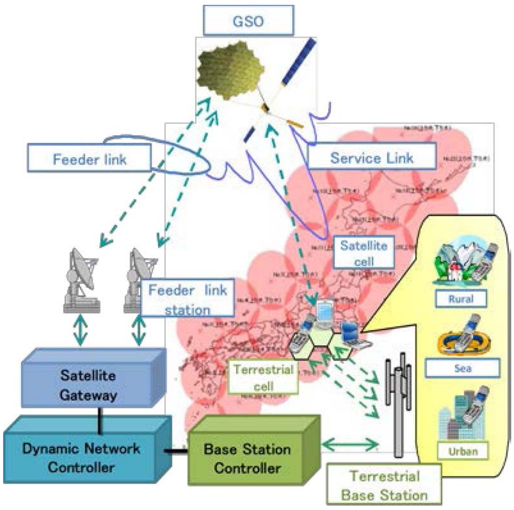


Figure 1 Conceptual figure of STICS

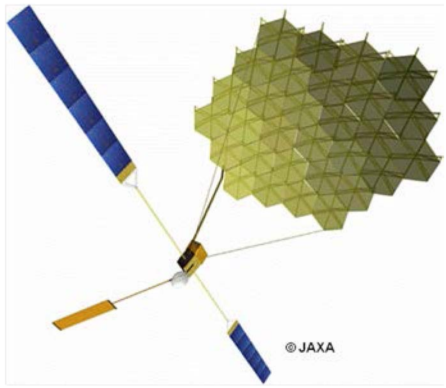


Figure 2 Outer view of STICS satellite

3. Satellite Configurations

STICS satellite, we need to cover wide service area not only Japanese Main Island but also exclusive economic zone (EEZ) such as +-2.0 degrees from geostationary orbit. So, we defined satellite antenna type as array feed reflector antenna just like ETS-VIII. On the other hand, we need high gain in +47dBi at the end of coverage (EOC). To meet this requirement, we defined geometrical parameter which is shown in figure 3. Reflector aperture size is 27m and F/D is 0.6. And defocus distance is 0.8m. Number of elements is around 100 and its array distance is 150 mm.

A small high-density feeding circuit for a multibeam antenna technology which can be expanding more than 100 beams is established. A feeding antenna with common use of Tx/Rx is deigned and measured. We have chosen patch antenna with square cup as an optimal antenna from several candidates.

In the satellite, full digital bentpipe transponder is adopted. Because it has great flexibility that is not depends on the modulation method compared to the regeneration relay transponder. And digital transponder of STICS has two characteristics. One is onboard digital beam former (DBF) that can be used to generate with more than 100 beams simultaneously. The other is a high-capacity channelizer for effective usage of feeder-link channel.

Figure 4 shows schematic diagram of STICS satellite. Left side shows user link of S band and right side shows feeder link which is considered Ka or Ku band. Singals from user terminal received feeding circuit of around 100 elements via user link reflector antenna. And about 100 beams were formed in Digital Beam Former. For the purpose of effective use of feeder link frequency, each signal of beam was passed through channelizer. In the channelizer, channel in use connected to feeder link and channel not in use is not connected to feeder link, so that feeder link bandwidth can be reduced. It can contribute effective use of frequency. Full digital bentpipe transponder was considered for this system, so high speed A/D and D/A

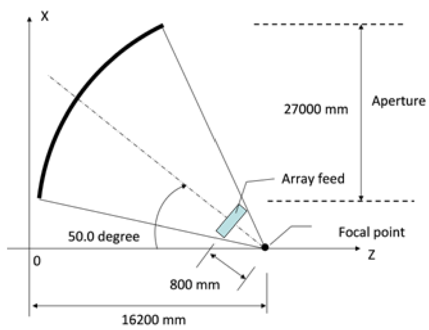


Figure 3 Reflector Parameter

converter, quadrature detection circuit, quadrature modulation circuit, digital signal processing unit using high capacity FPGA (Field-Programmable Gate Array) were adopted.

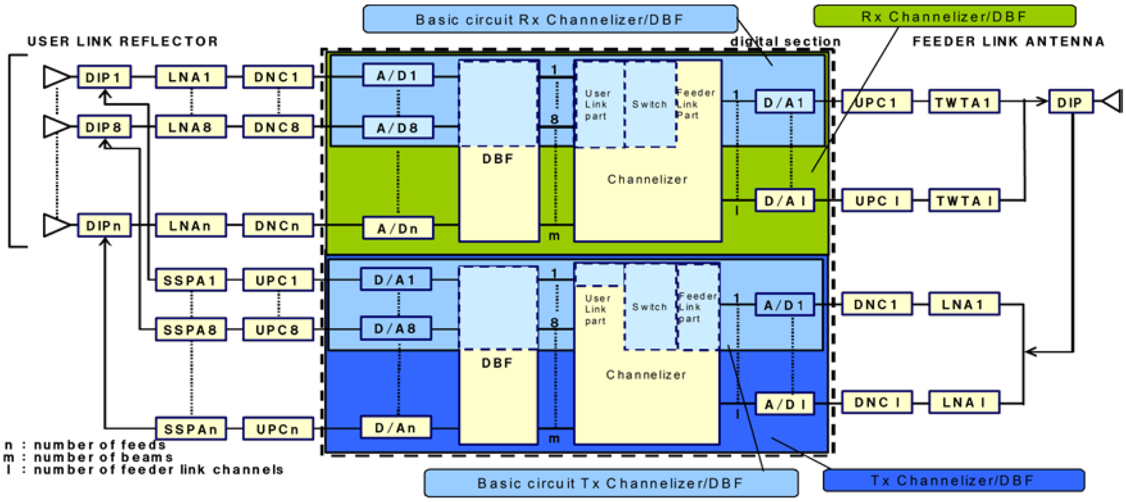


Figure 4 Schematic diagram of STICS satellite

4. Experimental result

We developed antenna element for this system, that four-point fed wideband circularly polarized MSA with a cavity antenna[4]. At first, mutual coupling of developed antenna element was measured. It was very low and around 35dB. Also, light weight (less than 250g) and small diplexer was developed which isolation between Tx/Rx is more than 80dB. As a small size test, small size array antenna model of 16 feeding antenna was developed. Figure 5 shows 16 elements array antenna as a small size model. Also, we made a small scale DBF/channlizer of 16 beam 16 elements. Its small size feeing part is evaluated by Planar Near Field Measurement system (NFM) in Kashima Space Research Center of NICT. Measured near field is converted into far field with taking into consideration of 27m ideal reflector. Figure 6 shows the contour pattern. Shape of main lobe pattern is quite good even in the edge of the service area. And performance of this antenna is confirmed.

Next, channelizer was developed for this system. For example, Transmitting channelizer which is shown in bottom part of Figure 4, Input feederlink bandwidth was 120MHz (30MHz x 4), and output beam number were 100. Figure 7 shows outer view of Tx DBF/channelizer and Figure 8 indicates input and output signal example. In the normal case, channelizer is assingned equal bandwidth in seven beams (from Beam 1 to Beam 7) when we assumed seven colored frequency arrangement. It shows leftside of figure 8. And if disaster was happened, traffic will be

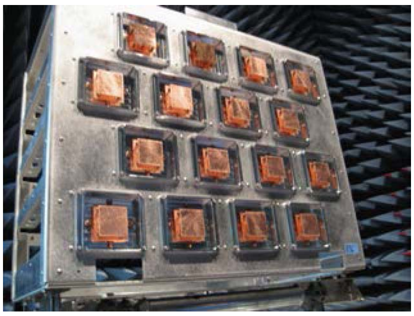


Figure 5 Small feeding array of 16 elements

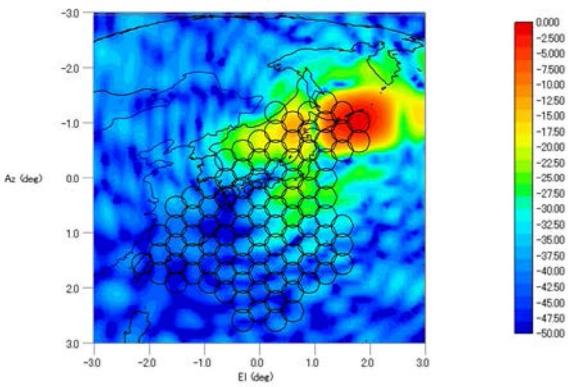


Figure 6 Estimated contour pattern of satellite (Measured feeding array and calculated reflector)

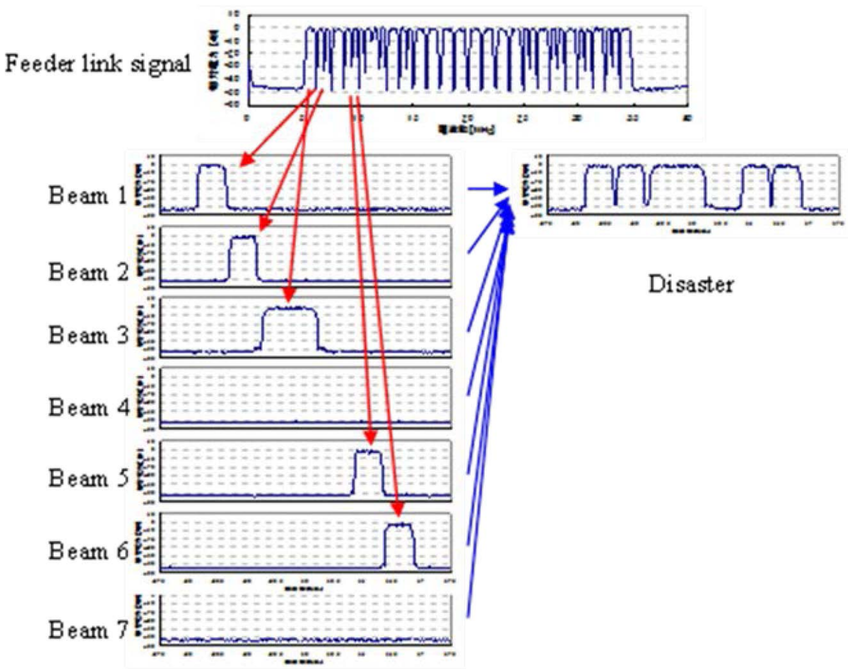
concentrated at disaster area. So, almost all frequency bandwidth of satellite should be allocated to disaster area. Right side of figure8 shows such status and full 30 MHz was assigned to Beam 1.

5. Summary

Figure 7 Tx DBF/channelizer unit

For small scale model of STICS satellite beam former and digital bentpipe system, NICT developed 16-element feeding antenna with Digital Beam Former and Channelizer for flexible usage of frequency. In the DBF, using NFM measured value and ideal 27mϕ reflector calculation, we confirmed aimed service area which is +-2.0 degree, can be available. For the channelizer, scalable frequency assignment in case of emergency disaster was confirmed.

Such digital transponder technology adapted here will enhance communication satellite flexibility and will establish new era of communication satellite.



Normal

Figure 8 Frequency allocation modification of normal/disaster using channelizer.

Acknowledgments

This study was conducted as part of the “research and development for the expansion of the radio wave resource” initiative of the Ministry of Internal Affairs and Communications. We wish to express our gratitude to all the people involved with us for their co-operation and assistance.

References

[1] Thuraya Satellite Telecom (http://www. thuraya.com/).

[2] SkyTerra Communications (www.skyterra.com)

[3] T.Minowa, M.Tanaka, N.Hamamoto, Y.Fujino, N.Nishinaga, R.Miura and K.Suzuki: “Satellite/Terrestrial Integrated Mobile Communication System for Nation's Security and Safety”, Trans IEICE on Communication (Japanese edition), VolJ91-B, No.12, pp.1629–1640.

[4] Y.Fujino, et.al., Experimental Demonstration of Four-Point Fed Wideband Circularly Polarized MSA with a Cavity, IEICE nat. conv. 2010, B-1-146.