Satellite Terrestrial Integrated Mobile Communication System as a Disaster Countermeasure

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Abstract

Creating a safer society requires communication methods available during disasters. This need has prompted the start of research and development to build a mobile satellite communication system for the satellite terrestrial common terminal. The system is called STICS (Satellite/Terrestrial Integrated mobile Communication System). A dual communication function that can connect to both the terrestrial system and the satellite system is formed by using a common terminal with a portable, handheld shape. This paper discusses the research and development and the current status of STICS.

1. Introduction

The utility of satellite-based mobile phone systems in disaster management is well known. Because of 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.

At present, using a small portable terminal, the Thuraya Satellite Telecom Co. provides satellite communication and global system for mobile (GSM) communications in more than 100 countries across the world including countries in the Middle East, Europe, North and Central Africa, and Asia[1].

Meanwhile, SkyTerra Communications is trying to introduce mobile communication systems that will improve frequency utilization efficiency by integrating the frequencies of terrestrial and satellite systems. It also plans to adopt a communication system that will make up for the lack of coverage from satellite systems by effectively employing a terrestrial system[2].

In the system used by SkyTerra, a satellite dish antenna with a diameter of 22 m and operating in the L band is used to cover all of North America with hundreds of spot beams. However, the communications system design for Japan needs to be unique because of differences in area and population distribution.

We therefore proposed a communication system that enables improvements in frequency utilization efficiency by integrating the frequencies of the terrestrial and satellite systems. A deployable antenna having a diameter of 30 m will be installed in the satellite and approximately 100 high-gain multibeams will be used to cover Japan and exclusive economic zones (EEZs)[3]. In this paper, we report on the status of R&D concerning STICS

2. Outline of STICS System

We have called our communication system 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 forms of communication. The handheld terminal is used for voice-data communication with a micro satellite antenna, and a portable terminal is used for data communications with a small satellite antenna.

The earth station and the base station are both equipped with a controller. They can be simultaneously managed

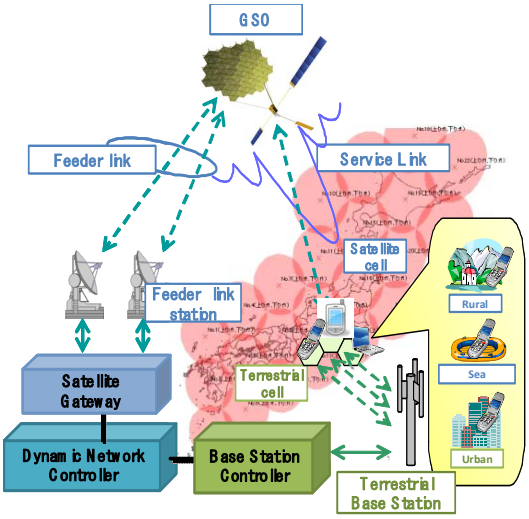

Figure 1 Conceptual figure of STICS

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using the common controller via a core network. Moreover, it can be used to connect to the public switched telephone network (PSTN) and to the internet through the core network (Figure 1).

In this system, frequency is assumed between 1980–2010 MHz and 2170–2200 MHz, which is in accordance with the allocation by Mobile Satellite System (MSS) in International Mobile Telecommunications-2000 (IMT-2000). Two frequency allocation methods is considered which named "nomal mode" and "reverse mode"(Figure 2).

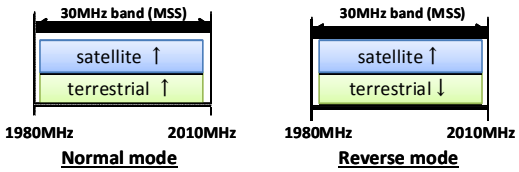

Figure 2 Two frequency allocation method

To create this system, high EIRP and G/T communication satellite is needed using a multibeam antenna with the reflector in the 30m class. The specifications for the satellite number of beams, antenna gain, and G/T are 100 beams, more than 47dBi, and more than 21dB/K, respectively[4]. Figure 2 is a conceptual figure of the STICS Satellite.

3. Research and Development Items

In the research and development (R&D) plan, we propose an appropriate method for introducing the communication system to Japan and examine the EEZs.
The R&D plan is divided to two parts: "satellite/terrestrial cooperation control technology [Term A]" and "interference avoidance between satellite/terrestrial system and frequency allocation [Term B]." We will explain each of these R&D items in detail.

3.1 Satellite/Terrestrial Cooperation Control Technology [Term A]

In this part, two research topics will be considered. First, an interference evaluation simulator is developed for evaluating the interference between the terrestrial system (the terrestrial terminal is included in the base station) and the satellite system (the satellite and satellite terminal are included), and the feasibility of using the frequency sharing method and resource allocation method is investigated.

Interference path is different with the "normal mode" and "reverse mode" shown in figure 3. In case of normal mode, satellite receives interference wave from terrestrial terminal and desired wave from satellite terminal. On the other hand, in the reverse mode, satellite receives interference wave from terrestrial base station and desired wave from satellite base station.

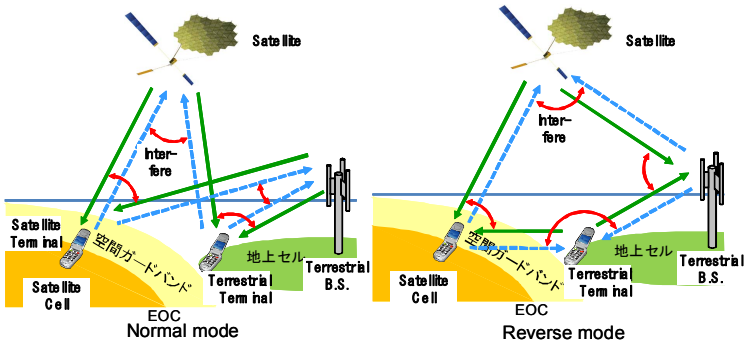

Figure 3 Interference path

The maximum frequency utilization efficiency is calculated by performing simulations for different frequency plans, cluster configurations, satellite beam designs, and widths of the spatial guard band. The spatial guard band denotes the area surrounding the satellite beam area, which may not be used for terrestrial applications at the same frequency as that for satellite use. As a preliminary result of the interference evaluation simulator, the total capacity of the satellite channel becomes 90×10^6, assuming the spatial guard band is 10dB and the EIRP of the terrestrial terminal is 0dBm in case of "normal mode".

In addition, we attempt to measure the interference wave from the terrestrial terminal and terrestrial base stations to determine the actual value of the EIRP of interference wave. This is because the interference power at the terrestrial system changes with the transmission power control (TPC) of the W-CDMA, if a conventional IMT system is considered as the terrestrial system. Figure 4 shows measurement setup using the airship and Figure 5 is photograph of airship and measurement antenna.

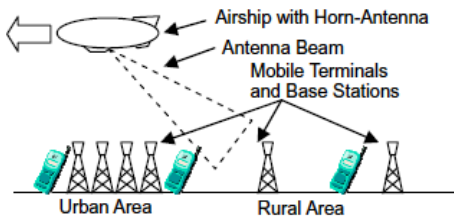

Figure 4 Measurement setup

We measured receiving level form north to south in the Kanto region. Figure 6 shows the results the interference wave from the terrestrial mobile terminal and from terrestrial base stations. As a result of airship measurement; receiving level from mobile terminal

was 25-30dB lower than receiving level from base stations. So, from this measurement we can conclude “normal mode” has advantage rather than “reverse mode”.

A more realistic simulation of interference evaluation simulator using this result is now being considered.

Figure 5 Photograph of airship and receiving antenna.

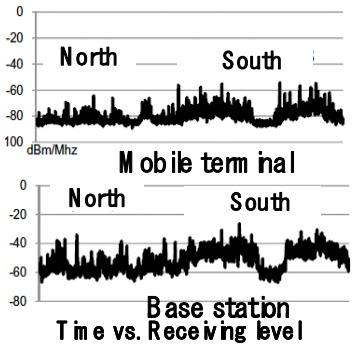

Figure 6 Receiving level

3.2 Interference avoidance between satellite/terrestrial system and frequency allocation [Term B]

In Term B, the following four studies are being carried out on the STICS satellite.

1. High linearity amplifier technology

Many interference waves with power significantly higher than that of the desired waves appear in the amplifier of the satellite in this system. Hence, the amplifier operates under poor working conditions. Therefore, attempts are being made to develop a high linearity S-band GaN amplifier (SSPA) operating at a power of approximately 10–20 W with efficiency of more than 60%. A high linearity low-noise amplifier (LNA) is also developed with the NF 1.1dB and IIP3 -25.0dBm.

Figure 7 shows gain compression vs. input power with different interference conditions for developed LNA. This LNA shows almost identical characteristics with or without high-level interference.

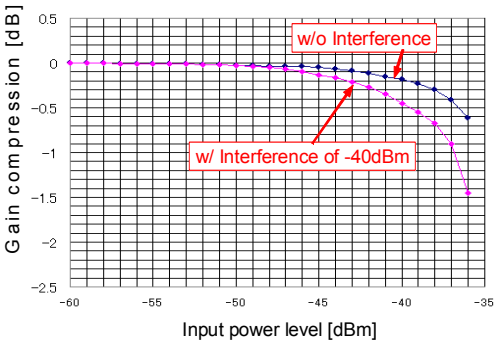

Figure 7 Gain compression vs. input power

2. Low sidelobe technology

The low sidelobe technology is adopted to suppress the interference between satellite multibeams.

In addition, a technique for correcting changes in the beam direction in the satellite is developed. This is because of change in thermal conditions at the large deployable reflector and other satellite structures [4].

For this reason, simulation software is now been written for large-size deployment antenna direction variation. This software is a function to be added to a transmitting excitation distribution simulator, to perform the analysis, design, and evaluation of the 100-beam class multibeam for the STICS satellite.

Using this simulator, to determine the beam direction of the antenna in orbit, the Rotating Element Vector method (REV method) is applied, computing the relative phase and amplitude. Signals from satellite are received at two or more ground stations.

It is also possible to presume compensation of beam direction variation (primary modification of the reflector surface) in an orbit and to calculate the excitation phase with compensating direction variation. This becomes the fundamental result for sidelobe suppression.

3. Super multibeam technology

A small high-density feeding circuit for a multibeam antenna technology that can be expanded to more than 100 beams is established. With this technology, a feeding antenna with shared use of Tx/Rx is designed. Antenna tape is “Four-Point Fed Wideband Circularly Polarized MSA with a Cavity”. Figure 8 shows the 19-elements array of the antenna. We also measured the mutual coupling of two elements with the result shown in figure 9. Mutual coupling was very low at approximately 35dB.

Figure 8 Feeding array antenna (19-elements)

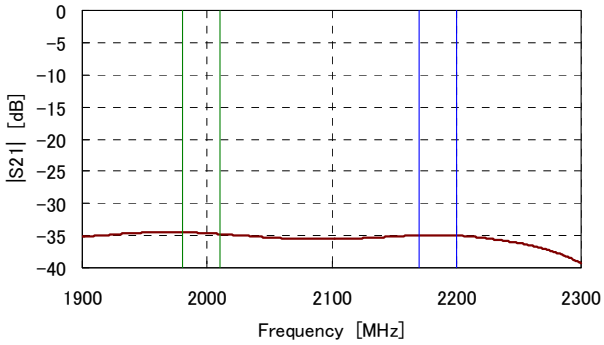

Figure9 Mutual coupling of two antennas.

4. Reconstruction of resource allocation technology.

This part has two aims. At first, the digital beam former (DBF) that can be used to develop onboard antennas with more than 100 beams is established.

Next, a high-capacity channelizer with a feeder-link bandwidth of more than 200 MHz is established.

For this purpose, we set up a DBF/channlizer simulator for software confirmation. Next we created a basic circuit for the DBF/channelizer. Next, we plan to develop DBF/channelizer for a small-scale array.

4. Conclusion

In this paper, we described a STICS from the viewpoint of the application of satellite communication systems for realizing a safe society, and the effective use of frequency. The R&D status of each STICS items was summarized.

5. Acknowledgments

This study was conducted as part of research and development to expand radio wave resources, an initiative of the Ministry of Internal Affairs and Communications. We wish to express our gratitude to all involved in this initiative for their co-operation and assistance.

6. References

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