Radio Frequency Equipment for High Maintainability and Availability in Remote Island Satellite and Disaster Relief Satellite Communications

Munehiro Matsui, Akira Matsushita, Mitsuru Nishino, and Fumihiro Yamashita

Abstract

The NTT Group uses satellite communications as a means of providing communications services to areas where deploying optical fiber or other communication facilities is infeasible such as remote islands or regions stricken by a natural disaster where residents are forced to take temporary refuge at evacuation centers. Against this background, NTT Access Network Service Systems Laboratories has been researching and developing a satellite communications system with the aim of making more efficient use of facilities and improving operability. This article introduces radio frequency equipment developed to achieve high maintainability and availability of remote island satellite and disaster relief satellite communications.

Keywords: power amplifier, maintainability, availability

1. Highly Efficient Satellite Communications System

The NTT Group uses satellite communications known for wide-area coverage and ease of network construction to provide communications services to areas where deploying a communication infrastructure made up of optical fiber, etc. is difficult. Such areas include remote islands and areas stricken by natural disasters where residents are forced to take temporary refuge at evacuation centers. NTT Access Network Service Systems Laboratories has been researching and developing the Highly Efficient Satellite Communications System (HESCS) for more efficient use and enhanced operability of satellite communications facilities. The NTT Group has been using this system to provide remote island satellite communications and disaster relief satellite communications services. A conceptual diagram of these services provided with the HESCS is shown in **Fig. 1**. Remote island satellite communications provides communications between a mainland station and island station if deployment of a submarine optical cable to that island is impractical, or it can serve as a backup circuit to a previously deployed submarine optical cable. Disaster relief satellite communications provides communications between a base station and terminal stations installed in a disaster-stricken area. It can rapidly deploy provisional circuits to evacuation centers in that area and provide special public telephones and Internet-connection services.

The basic configuration of the HESCS for such services is shown in **Fig. 2**. This system consists of satellite circuit-terminating equipment called the

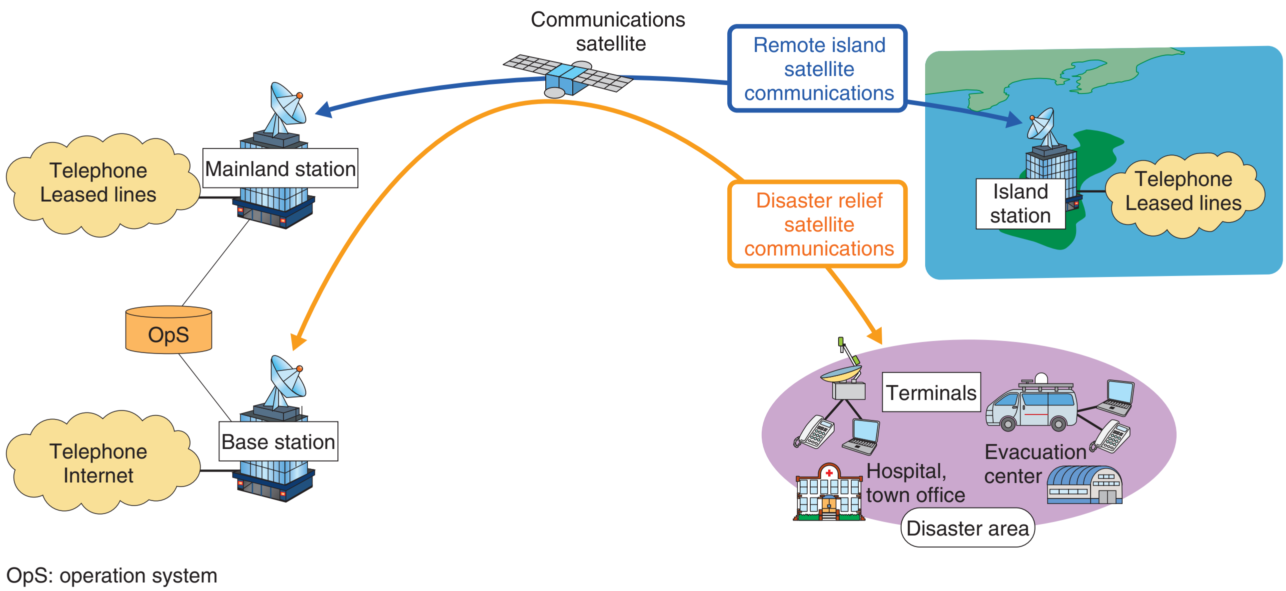

Fig. 1. Services provided with Highly Efficient Satellite Communications System (HESCS).

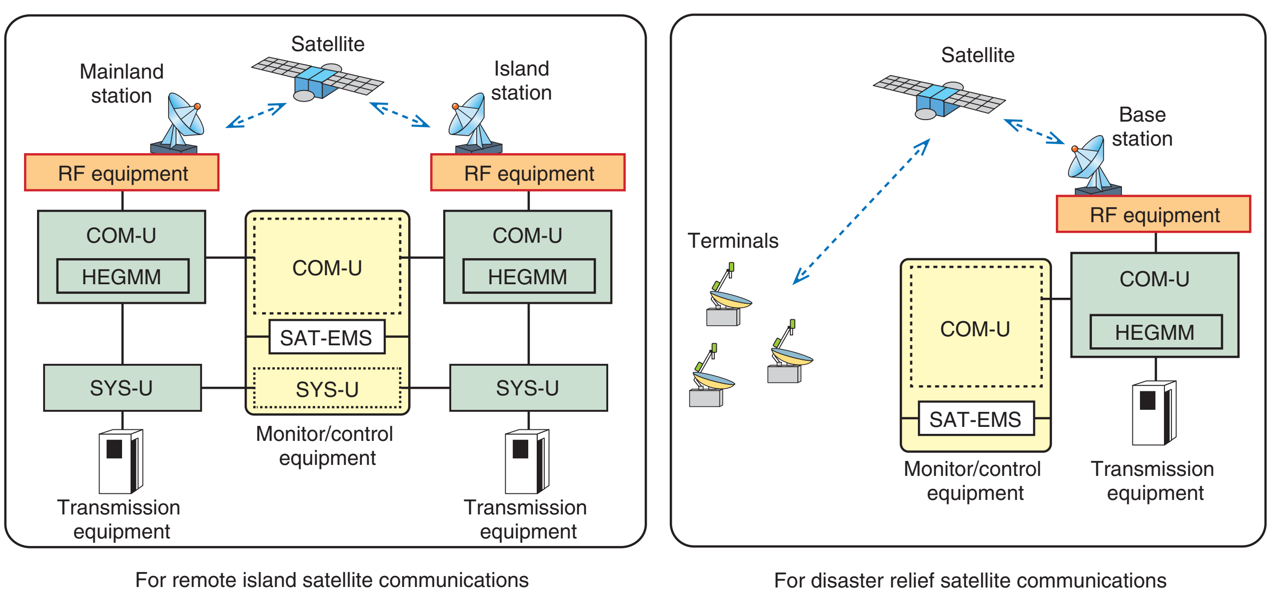

Fig. 2. Configuration of HESCS.

Common Unit (COM-U) equipped with the Highly Efficient Group Modem Module (HEGMM), satellite circuit-terminating equipment called the System Unit (SYS-U) that connects the COM-U to transmission equipment, the Satellite-Element Management System (SAT-EMS) that monitors and controls the above units, and radio frequency (RF) equipment, the focus of this article. The COM-U is a satellite communications modem that makes efficient use of satellite transponders by incorporating the HEGMM [1]. The SYS-U, meanwhile, links the mainland with a remote island for remote island satellite communications and makes circuit connections via satellite circuits. In addition, the RF equipment converts the intermediate

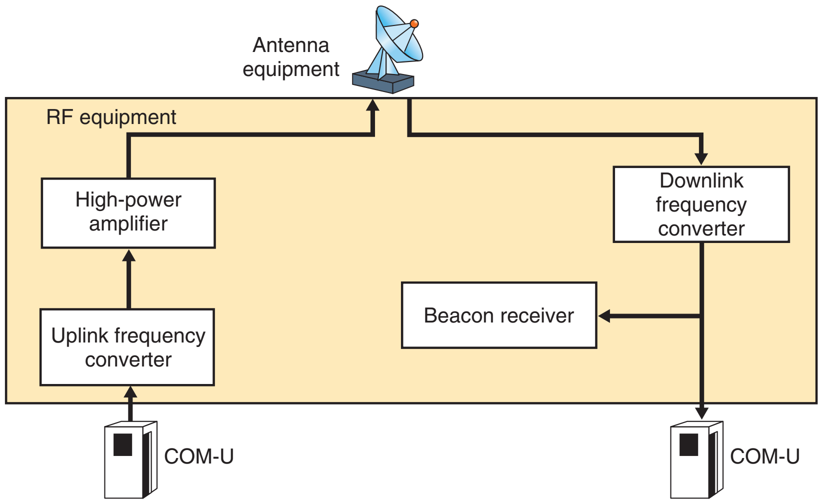

Fig. 3. Configuration of RF equipment.

frequency (IF) signals output by the COM-U to high-frequency radio signals (RF signals) for output via antenna equipment. The same RF equipment converts incoming RF signals to IF signals and outputs them to the COM-U. Finally, the SAT-EMS monitors and controls the various types of equipment making up the HESCS such as the SYS-U, COM-U, and RF equipment.

2. Development of RF equipment

The configuration of the RF equipment is shown in **Fig. 3**. The RF equipment consists of an uplink frequency converter, high-power amplifier, downlink frequency converter, and beacon receiver. The uplink frequency converter converts IF signals output from the COM-U to RF signals, and the high-power amplifier amplifies the power of those RF signals before outputting them to the antenna equipment. The downlink frequency converter, on the other hand, converts the RF signals received by the antenna equipment to IF signals. The beacon receiver controls transmission power and antenna direction based on the received beacon signals. The high-power amplifier, which uses large amounts of power, requires periodic maintenance to prevent failures and must therefore have high maintainability. It must also be able to provide a stable level of communications quality at all times through uplink power control that matches the current conditions such as the number of connected terminal stations. It must therefore have high availability. In the face of these requirements, NTT Access Network Service Systems Laboratories has developed a high-power amplifier for the HESCS to improve maintainability in remote island satellite communications and high-power-amplifier module for the HESCS to improve availability in disaster relief satellite communications.

(1) High-power amplifier for improving maintainability

Remote island satellite communications provides communications between a mainland station and remote island station via a satellite in geostationary orbit (at an altitude of approximately 36,000 km). A frequently used high-power amplifier in satellite communications is a traveling wave tube amplifier (TWTA). The TWTA, while capable of achieving high-output amplification at low cost, requires that the traveling tube be periodically replaced resulting in high maintenance costs. The maintenance of remote island station facilities, in particular, can increase maintenance costs due to travel expenses of maintenance personnel, shipping costs of parts and components, etc. On the other hand, technology for achieving a solid state power amplifier (SSPA), which requires no periodic replacement, has been progressing toward high-output capabilities.

Against this background, NTT Access Network Service Systems Laboratories developed an SSPA with a maximum output of 200 W for remote island satellite communications. A view of the interior section of this SSPA is shown in **Fig. 4**. The developed SSPA is equipped with four gallium nitride field effect transistors (GaN-FETs) enabling a maximum

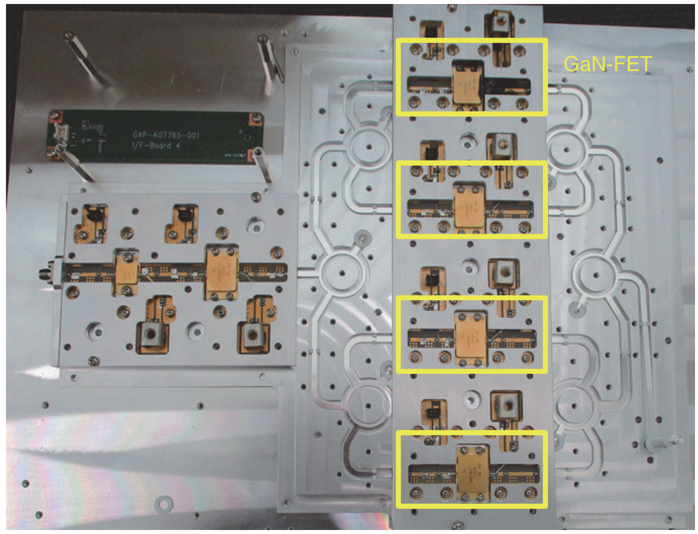

Fig. 4. Photograph of SSPA interior.

output of 200 W. A linearizer is also installed in the SSPA pre-stage to suppress interference that propagates outside the amplifier's own band and that arises during signal amplification in the nonlinear region of a power amplifier. The linearizer processes the signal prior to SSPA input, thereby suppressing the interference generated after SSPA output. Using a technique developed by NTT Access Network Service Systems Laboratories, linearizer parameters are adjusted so that the power ratio between the SSPA's own signal and outside-band interference reaches the required value [2]. Parameter adjustment originally had to be carried out using a multicarrier signal consisting of a maximum of about 30 carriers used during service operation. The developed technique, however, enables parameter adjustment to be completed with the signals of only two carriers.

(2) High-power amplifier for improving availability

Disaster relief satellite communications provides communications between a terrestrial base station and terminal stations via a satellite in geostationary orbit. For this service, a decision is made as to the number of connected terminal stations accommodated by a single carrier in a multicarrier signal as well as required transmission power per carrier. In the case of many terminal-station connections, the number of operating carriers increases, which requires the base station to have high transmission power. Base station operation takes on a redundant configuration to ensure that communications services are provided as usual even during a disaster. That is, the service uses one base station installed in eastern Japan and one in western Japan, and in normal conditions, each base station can cover all of Japan with the ability to connect to terminal stations anywhere in the country. These base stations function as a backup to each other, and in the event that either stops operating during a major disaster, the other will cover the entire country to enable communications with terminal stations. In the case of operation by a single base station, there will be many terminal stations to be connected to that base station, requiring high transmission power compared with normal conditions. At such a time, transmission power from a single high-power amplifier may not be sufficient and communications quality may drop, impeding communications services.

To mitigate this concern, NTT Access Network Service Systems Laboratories developed a high-power-amplifier module equipped with two high-power amplifier units. The equipment configuration and external view of this high-power-amplifier module are shown in **Figs. 5** and **6**, respectively. The module consists of two TWTA units as the high-power amplifiers plus a switch/power-divider unit and power-combiner/phase-synthesizer unit. The controller controls the operation of the two TWTA units and switch/power-divider unit and controls two modes. The first of these two modes is simple output mode, which is used during normal operation of the two base stations. At this time, only one TWTA in the module is operating while the other serves as a backup

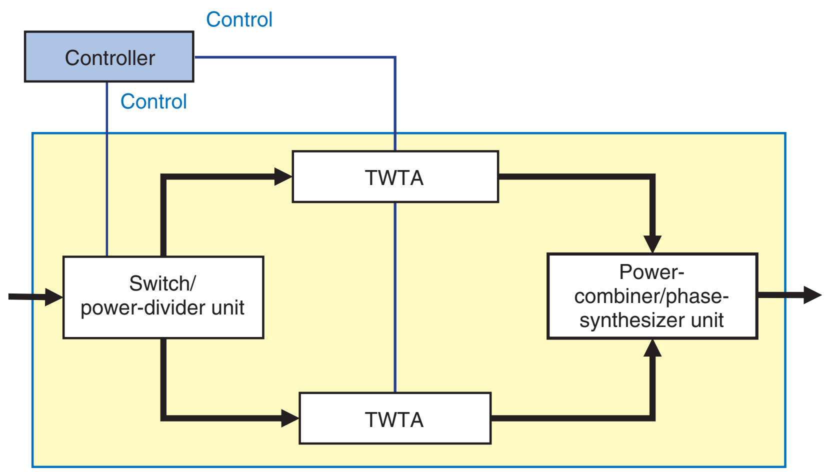

Fig. 5. Configuration of high-power-amplifier module for disaster relief satellite communications.

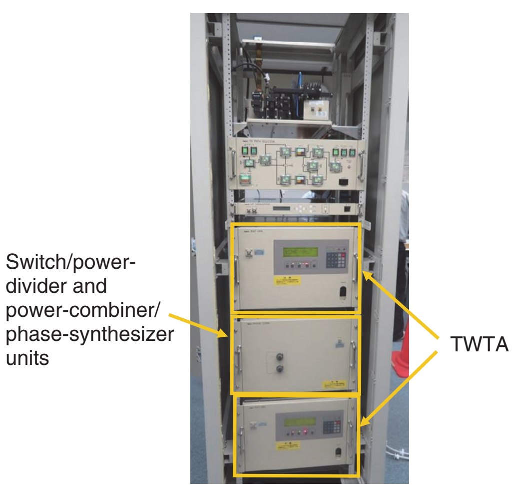

Fig. 6. External view of high-power-amplifier module for disaster relief satellite communications.

in the event of a failure. The second is combined output mode, which is used when only one base station is operating. At this time, both TWTA units of that module are put into operation, and the output from each are combined and output. This scheme prevents transmission power from becoming insufficient even when many terminal stations are connected during operation of only one base station, thereby maintaining communications quality.

3. Future plans

This article introduced RF equipment developed as part of NTT's HESCS with the aim of improving system maintainability and availability. Looking to the future, NTT laboratories are committed to researching and developing satellite communications systems including the development of advanced terminal stations with an eye to reducing costs and improving usability.

References

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