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Technology Reports

Special Articles on WIDESTAR II High-speed Mobile Satellite Communications Service for Diverse Satellite Communications

WIDESTAR II Satellite Mobile Station

The WIDESTAR II service began in April 2010, in response to demand for upgraded equipment and increased speeds from the WIDESTAR domestic satellite communications services which began in 1996, and new mobile stations were developed for the new service. The portable mobile stations and marine/vehicle-mounted mobile stations developed have enabled increases in communications speed, and the improved user interface and support for new services such as G3FAX through packet communications has increased convenience for users.

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1. Introduction

The WIDESTAR service [1], which began providing domestic mobile satellite communications services using the S-band in 1996, began a satellite packet communications service [2] in 2000, and WIDESTAR Duo [3] stations came onto the market in 2003. At this time, we have developed mobile stations for the new WIDESTAR II service, to accompany upgrades to the WIDESTAR service radio equipment.

In this article, we give an overview of the specifications, connection configurations and functionality of the new portable and marine/vehicle-mounted stations for the WIDESTAR II service, which began in April 2010. We also describe voice communications and call control methods, as well as major features such as high-speed data communications and FAX services used with the new stations, and particular features of the portable and marine/vehicle-mounted stations.

2. WIDESTAR II Satellite Mobile Stations

2.1 Mobile Station Overview

Two types of mobile station were developed: a portable mobile station which can be taken into mountainous areas or disaster sites and is intended for semi-static use, and a marine/vehicle-mounted station which is intended for use in moving boats and vehicles.

External views of the mobile stations are shown in **Photo 1**, and the specifications are given in **Tables 1** and **2**.

The stations use the same 2.6/2.5 GHz frequency band as the WIDESTAR service, which is resistant to attenuation by precipitation and other changing weather effects. Parameters including frequency band, maximum transmission power, modulation schemes and radio connection protocols are equivalent or extensions of those used with the WIDESTAR service, and

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(a) Satellite FAX adapter 01
(b) Satellite handset 01 and satellite portable station 01
(c) Satellite marine/vehicle-mounted antenna 01
(d) Satellite marine/vehicle mounted station 01

Photo 1 External views of mobile stations

Table 1 Satellite portable station 01 specifications

	WIDESTAR Ⅱ Satellite portable station 01	Earlier model WIDESTAR Duo
Frequency bands	Transmission frequencies : 2,660-2,690 MHz Reception frequencies : 2,505-2,535 MHz	
Maximum transmit power	2.0 W	
Modulation/Demodulation	Uplink/Downlink : π/4-Shift QPSK	
Packet transmission rate	Best-effort type : Uplink max. 144 kbit/s, Downlink max. 384 kbit/s Guaranteed speed type : Uplink/Downlink 64 kbit/s	Uplink max. 4.8 kbit/s, Downlink max. 64 kbit/s
Voice coding method	G.729a (8 kbit/s)	PSI-CELP (5.6 kbit/s)
Dimensions	Approx. 180×39×196 mm	Approx. 180×42.8×200 mm
Weight	Approx. 1.3 kg (incl. battery pack)	Approx. 1.7 kg (incl. battery pack)
Battery pack continuous talk time	Approx. 2.2 h	Approx. 2 h
Battery pack continuous standby time	Approx. 26 h	Approx. 20 h

PSI-CELP : Pitch Synchronous Innovation Code Excited Linear Prediction
QPSK : Quadrature Phase Shift Keying

WIDESTAR service accessories such as external antennas can be used with the new stations.

Examples of connections for voice/data communication are shown in **Figure 1**, and for FAX use are shown in **Figure 2**. Both the portable and the marine/vehicle-mounted stations use a handset connected to a 10-line interface for voice communication and an RJ-45 interface connected to a PC or other device for data communications. The FAX adapter also has a router function in addition to G3FAX communications, so a LAN can be easily configured to

Table 2 Satellite marine/vehicle-mounted station 01 specifications

		WIDESTAR Ⅱ Satellite marine/vehicle mounted station 01	Earlier models: WIDESTAR Marine Phone	Earlier models: WIDESTAR Duo (vehicle mounted)
Frequency bands		Transmission frequencies : 2,660-2,690 MHz Reception frequencies : 2,505-2,535 MHz		
Maximum transmit power		2.0 W		
Modulation/Demodulation		Uplink/Downlink : π/4-Shift QPSK		
Packet transmission rate		Best-effort type : Uplink max. 144 kbit/s, Downlink max. 384 kbit/s Guaranteed speed type : Uplink/Downlink 64 kbit/s	Uplink max. 4.8 kbit/s, Downlink max. 64 kbit/s	
Voice coding method		G.729a (8 kbit/s)	PSI-CELP (5.6 kbit/s)	
Dimensions	Mobile station	Approx. 180×39×196 mm	Approx. 150×70×250 mm	Approx. 222×65×211 mm
	Antenna	Approx. 300 φ ×145 mm	Approx. 300 φ ×150 mm	Approx. 260 φ × 47 mm
Weight	Mobile station	Approx. 2.5 kg	Approx. 3 kg	Approx. 4.8 kg
	Antenna	Approx. 4.0 kg	Approx. 5 kg	Approx. 2.5 kg

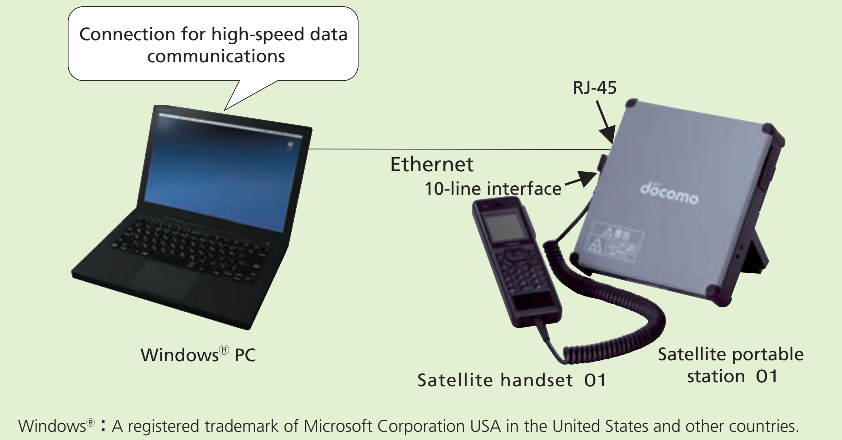

Figure 1 Examples of connections for voice and data communications

Figure 2 Example connections when using FAX

connect multiple PCs to the FAX adapter.

2.2 Major Mobile Station Features

1) Satellite (Base Station) Selection Process

The WIDESTAR II service has two satellites, N-STAR c and d, and base stations for each of them, and stations give priority to operation with one of the satellites and its base station. To ensure that stations do not preferentially use either of the satellites (base stations), the stations have an original distributed algorithm for equally dividing use of the two satellites (base stations), equalizing the number of stations connected to each satellite (base station) and thus the loads on them as well.

Also, when either satellite (base station) is temporarily out of service, as during sun transit phenomenon*1 or operational faults, stations autonomously connect to the other satellite (base station), allowing continuous use of the service.

2) Voice Communication Using Session Initiation Protocol (SIP)*2

For voice communications, a C/N of 5 dB (C/N is the power ratio of carrier signal to noise) and error rates of 10^{-4} or less are achieved using adaptive Viterbi decoding*3/demodulation, which implements Viterbi decoding and carrier reconstruction at the same time.

- Call control

The network for WIDESTAR II is entirely IP, so SIP, which is compliant with RFC3261 and highly compatible with IP, has been adopted as the call control protocol for the mobile stations.

Call control signaling with SIP is all text-based, so messages are larger than for binary messages by a factor of ten. This is an issue because control channels are designed with low capacity, to use satellite power more efficiently, and because increasing the message size can result in delays when connecting calls due to large Round-Trip Delay (RTD). To deal with this, the WIDESTAR II service has adopted an original compression scheme used only on the satellite link connecting mobile stations to base stations. This reduces the SIP messages to approximately a fifth of their normal size and realizes short call-connection times.

- Voice priority function

The WIDESTAR II service provides voice, data and G3FAX communications, but in times of emergency, most usage is expected to be voice. Because of this, the mobile stations have been equipped with a voice-priority function that allows important voice communication to be initiated and received while data or G3FAX communication is in progress. As an example,

*1 **Sun transit phenomenon**: When the satellite is eclipsed, overlapping with the sun as seen from the base station antenna, so that communication quality degrades due to noise generated by the sun. This occurs twice a year, in spring and fall, for about one week each.

*2 **SIP**: A call control protocol defined by the Internet Engineering Task Force (IETF) and used for IP telephony with VoIP, etc.

*3 **Viterbi decoding**: A type of decoding for convolutional codes that estimates the most likely state transition from the received signal and the preceding bit pattern.

the voice-priority function notifies the user of an incoming call, even during data or G3FAX communication, using modified call-control handling and handset display mechanisms, allowing the user to decide whether or not to switch to voice communication.

3) High-speed Data Communications

Turbo coding methods*4, which approach theoretical limits, are used for packet communication and achieve error rates of 10^{-6} or less with a C/N of 5 dB. Turbo coding adjusts the coding rate according to line conditions, allowing it to provide stable data communication in environments with poor radio channel quality and allowing WIDESTAR II stations to achieve best-effort speeds of up to 144 kbit/s on the uplink and 384 kbit/s on the downlink, and a guaranteed speed of 64 kbit/s on both compared to speeds of up to 4.8 kbit/s on the uplink and up to 64 kbit/s on the downlink for earlier devices.

Another feature of the system is that best-effort or guaranteed speeds can be selected according to application by the user through the handset or a PC.

Users can easily display packet-use cumulatively or for recent communication for best-effort communication, and can display cumulative communications time for guaranteed-speed communication. This allows them to be aware of the criteria for communications costs by checking these values.

4) Easy-to-use User Interface

The handset is the same for both the portable and the marine/vehicle mounted stations. With the handsets for earlier devices, functions were selected by entering a menu number, but with the new handsets, all operations and displays can be selected from the handset menu, allowing easier operation (**Photo 2**).

5) G3FAX Services via Packet Communications

An illustration of using FAX services with WIDESTAR II is shown in **Figure 3**.

When a user sends a FAX document from a G3FAX machine, it is sent to the FAX adapter using the regular T.30 protocol. The FAX adapter converts the data in the received FAX document to a Tagged Image File Format (TIFF) file, and after storing it, transmits it as an e-mail attachment using the Simple Mail Transfer Protocol (SMTP). After the e-mail sent from the FAX adapter has passed through the satellite channels, it is sent to an iFAX®*5 server provided by NTT Communications Corporation. The TIFF file attached to the e-mail message is converted back to a FAX document by the iFAX server and delivered to the destination G3FAX machine by standard phone lines. To receive a FAX, the FAX data is stored on the FAX gateway as a TIFF file attached to the reception e-mail message and the mobile station is notified that a FAX has arrived. When the FAX adapter receives a FAX incoming notice from the mobile station, it retrieves the FAX as an e-mail message from the FAX gateway using Post Office Protocol 3 (POP3), and stores it in the FAX adapter. Then the FAX document is restored from the attachment on the stored e-mail message and output to the G3FAX machine connected to the FAX adapter.

6) Services using the FAX Adapter

The FAX adapter which provides the G3FAX service contains a router function, so it can also be used for data communications by PC's connected to a LAN. The FAX adapter also supports unattended operation, through an automatic transmission function. The automatic transmission function is able to automatically connect to a satellite channel and transmit FAX messages upon receiving an IP-data trigger from a PC on the LAN whose IP address has been preconfigured for automatic trans-

Photo 2 Satellite handset 01 external view

*4 **Turbo coding method**: A type of error-correction coding method, developed in 1993, which approaches the maximum theoretical transmission speed determined from Shannon's law (the theoretical maximum transmission speed over a noisy transmission path).

*5 **iFAX®**: A registered trademark of NTT Communications Corporation.

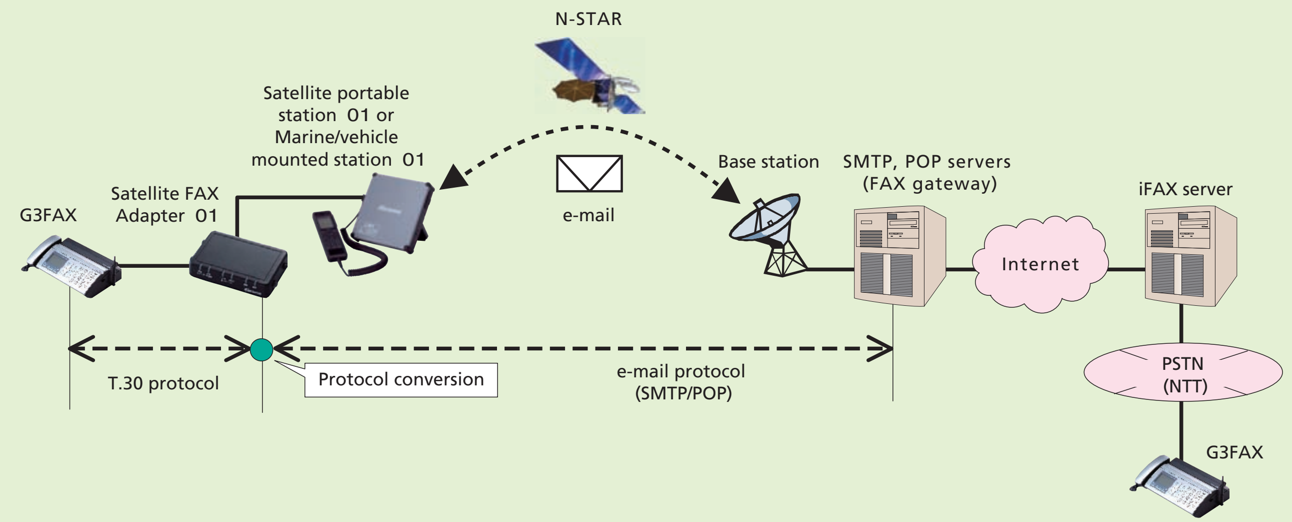

Figure 3 Use of the FAX service

mission on the FAX adapter. This allows for unattended transmission of data such as telemetry[*6].

2.3 Features of the Portable Mobile Station

Features of the portable station, which can be used in environments with no external power and can be easily transported, are described below.

1) Compact and Light-weight

The high-frequency circuits in the portable station adopt a sliding Intermediate Frequency (IF)[*7] method using a local oscillator[*8] shared by the transmission mixer[*9] and orthogonal modulator. The receiver system adopts a low IF method which converts the received Radio Frequency (RF)[*10] signal using an image rejection mixer[*11], directly to an IF that can be processed by the A/D converter. Adopting these two approaches allowed the implementation area to be reduced by reducing the scale of the circuits. Further reductions in size were achieved by converting digital circuits, which were separate parts in the WIDESTAR Duo, into LSI and reducing the number of parts in development of the portable mobile station.

2) Lithium-ion Battery[*12] Pack

Using a battery pack enables the portable station to be used in environments where external power is not available. The battery pack uses mainstream lithium-ion cell batteries. The main advantage of this is that the battery pack is approximately 185 g lighter than the nickel metal hydride battery pack used in the WIDESTAR Duo station. Additionally, we were able to extend the continuous talk time to approximately 2.2 hours, and the continuous standby time to approximately 26 hours by increasing the capacity of the battery pack to about 1,000 mAh.

Lithium-ion batteries are also less likely to spontaneously discharge rapidly, so they are able to maintain battery capacity longer than nickel metal hydride batteries, and they can provide a stable power supply for satellite portable stations, when the power has been turned off or in times of disaster or emergency.

On the other hand, the following measures were taken with the battery packs in order to ensure safety when using the lithium ion batteries.

- Protection from overcharging
- Accurate detection of thermal irregularities using multiple thermistors[*13]
- Internal shorts prevented by installing an insulating plate

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*6 **Telemetry**: Measurements and observations of an object observed remotely and data obtained from the object.

*7 **IF**: A frequency to which a high-frequency signal is converted to enable demodulation.

*8 **Local oscillator**: A circuit which oscillates at a local frequency that is used for converting to a high-frequency signal for transmission.

*9 **Transmission mixer**: A circuit which converts an intermediate frequency to a high-frequency signal.

*10 **RF**: A high frequency used for transmitting and receiving radio waves.

*11 **Image rejection mixer**: A frequency conversion circuit, used to convert a high frequency signal to an intermediate frequency, which has the property of suppressing harmonics generated.

2.4 Features of the Marine/Vehicle-mounted Stations

The marine/vehicle mounted mobile stations consist mainly of a tracking antenna, which controls tracking of the direction of the satellite, and the marine/vehicle-mounted mobile station, which performs processing for transmission and reception. The tracking antenna is positioned on the outside of the boat (or vehicle), while the marine/vehicle mobile station is placed inside, and the two are connected together easily using a single coaxial cable.

A block diagram for the marine/vehicle mounted mobile stations is shown in **Figure 4**. When the satellite marine/vehicle mounted antenna first begins to acquire the satellite, it rotates to detect the direction yielding the strongest reception level, and after acquiring the satellite, it performs tracking control for the satellite direction yields the maximum antenna gain[*14].

In contrast to the tracking antenna for the WIDESTAR Duo, which adopted a step-tracking method[*15], the new tracking antenna adopts a conical scanning method (**Figure 5**). Conical scanning scans the antenna beam in a conical shape when tracking the satellite and provides excellent communications quality improvement compared to the step tracking method in the following ways.

- Step tracking scans along only one axis at a time, either along the azimuth or elevation, requiring longer time from beginning to end of the scan. Conical scanning scans both at the same time for shorter scan times.
- Since the scan time is longer for step scanning, a step interval of six degrees was used to account for changes in the satellite direction during the scan, but since the conical scanning can be completed more quickly, a smaller scan interval of two degrees is used, reducing the amount of error.

Also, by adding a special receiver circuit for tracking to the marine/vehicle-mounted mobile stations, processing for tracking and reception could be separated, allowing time required for initial capture to be reduced to 15 s from the 54 s required with the WIDESTAR Duo marine device.

3. Conclusion

In this article, we have described an overview of the portable and marine/vehicle-mounted mobile stations for the WIDESTAR II service. These newly

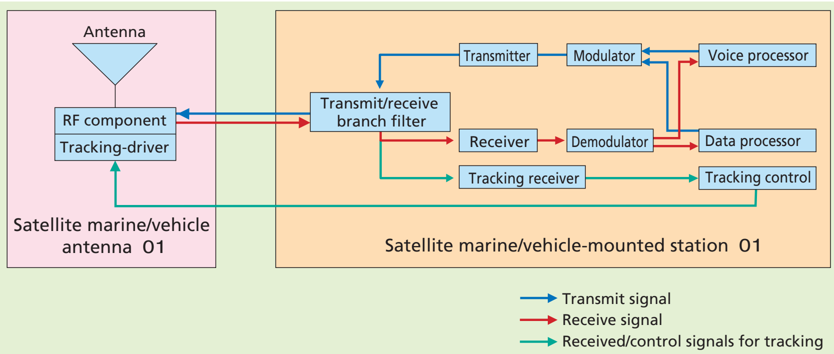

Figure 4 Block diagram of marine/vehicle mobile station

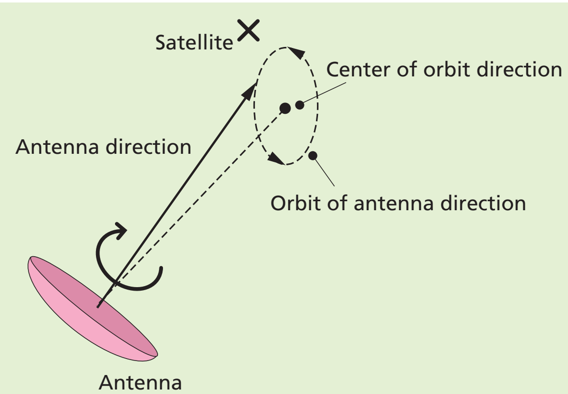

Figure 5 Conical scanning method

*12 **Lithium-ion battery**: A type of rechargeable battery (secondary battery) in which charging and discharging are perfomed by the movement of lithium ions through the electrolyte.

*13 **Thermistor**: A semiconductor element which changes electrical resistance greatly with changes in temperature.

*14 **Antenna gain**: The power emitted by an antenna relative to an ideal antenna.

*15 **Step-tracking method**: A tracking method in which the antenna direction is adjusted to maximize the level of the received signal by moving the antenna by small-angle steps at fixed intervals in time and space, and measuring the reception level before and after each movement.

developed stations provide higher data communications speeds, and more convenience for users through the more-usable handset, menu structure and display screens. These improvements should enable the stations to be used to meet an even wider variety of needs.

In the future, we will continue our study towards realizing mobile stations that are smaller, communicate faster and cost less.

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