Leaflet

Anritsu Advancing beyond

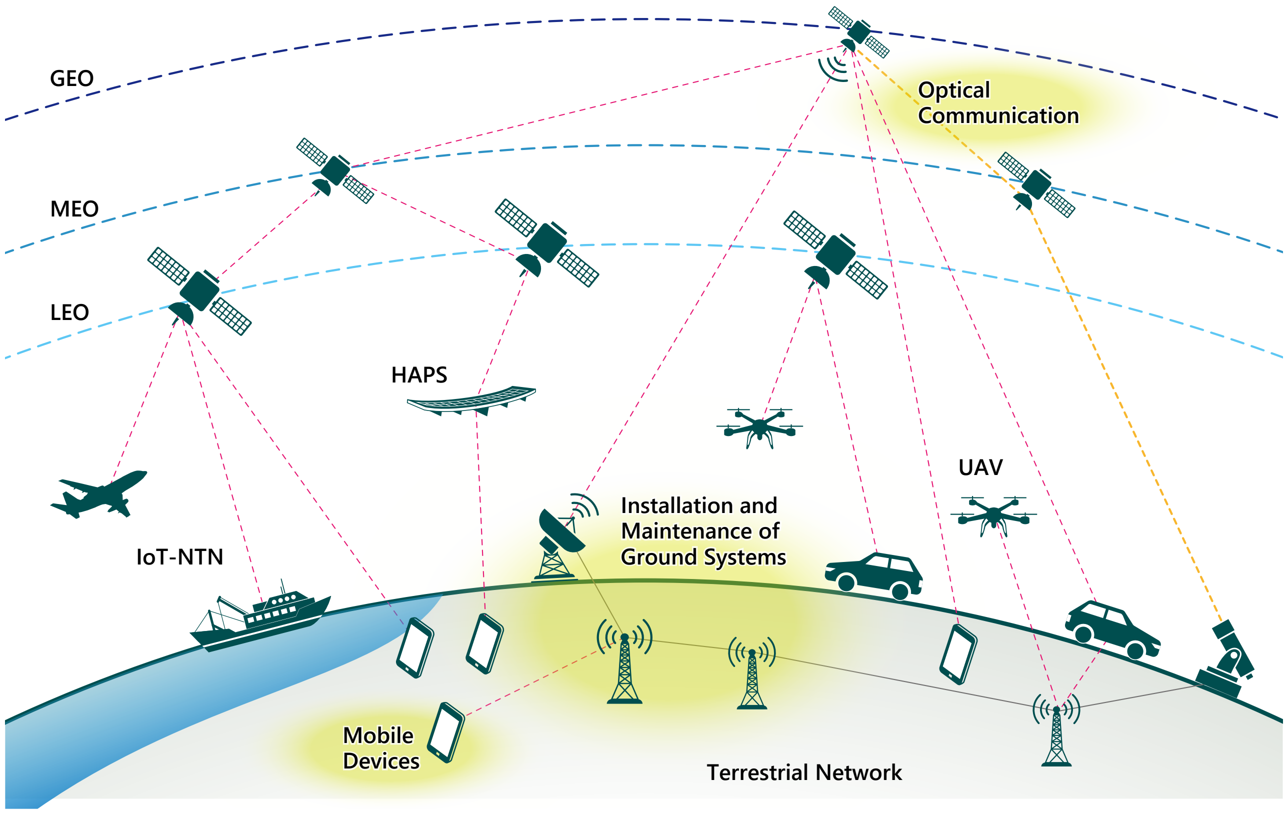
Non-Terrestrial Networks (NTNs) Test Solutions Use Cases

Space, Satellites, Aviation, etc.
Communication Quality Issues and Test Solutions

Non-Terrestrial Networks (NTN) provide communications in areas that cannot be covered by terrestrial networks, such as mountainous regions, in the air, and mid-ocean. An NTN is a network that utilizes satellite constellations and High Altitude Platform Stations (HAPS) to expand mobile communication areas, ensure communications during disasters, and provide ultra-high speed and ultra-low latency communications services using a hybrid of wireless and optical technologies. The use of space and satellites is expanding against a backdrop of growth in the next-generation information and communications infrastructure.

Anritsu contributes to the evaluation of communication quality in space/satellite, defense, aviation, marine, etc. with measurement solutions that utilize the experience and knowledge it has cultivated in evaluating mobile (5G/LTE) and network infrastructures.

NTNs are already utilizing a variety of platforms, including satellites in geostationary Earth orbit (GEO), medium Earth orbit (MEO), and low Earth orbit (LEO), as well as aircraft. In the field of Unmanned Aircraft Systems (UAS), demonstration experiments are also underway to put NTN using HAPS and Unmanned Aircraft Vehicles (UAV), and so forth.



NTN Market Trends

According to Global Information, Inc., the scale of the global 5G non-terrestrial networks market is expected to grow from USD 5.1 billion in 2023 to USD 31.19 billion by 2031, at a CAGR of 25.40% during the forecast period 2024-2031 [1].

To date, communication services have mainly been provided via GEO, but recently, satellite communication operators such as SpaceX's Starlink, Amazon's Kuiper, and OneWeb have deployed large-scale LEO constellations to provide communication services to general users and businesses.

For example, Starlink had launched approximately 6,000 satellites as of April 2024. The company provides best-effort services with download speeds of up to 220 Mbps and upload speeds of up to 25 Mbps. On the other hand, OneWeb is a dedicated line service with a guaranteed communications bandwidth, offering download speeds of 195 Mbps and upload speeds of 32 Mbps. The advantage of satellite communications is that, as the altitude of the satellite increases, the area that each satellite can cover also increases. However, there are disadvantages, such as data transmission delays due to the long distances between the satellite and the ground, and the high costs of launching and operating the satellite.

Additionally, HAPS, which fly in the stratosphere more than 20 km above the ground, are currently being developed and tested. Unlike satellites, which require rocket launches, HAPS can be produced at low cost and are relatively easy to deploy in the air. They can also be deployed quickly to specific areas in the event of a disaster. However, because they operate at a lower altitude than satellites, their coverage area is limited. In addition, while they would ideally be able to stay airborne for very long periods, limitations on their flight time due to battery life and the charging efficiency of solar panels are an issue.

[1] Source: Global Information Inc.

https://www.gii.co.jp/report/mx1536767-5g-ntn-market-assessment-by-component-by-geography.html

To provide communications services in countries around the world, satellite communications operators are collaborating with the mobile communications operators and communications equipment vendors listed in the table below to prepare for the launch of services such as satellite broadband, Direct-to-Device (D2D) communications between satellites and terminals such as smartphones, and satellite IoT. Several network architectures have been proposed to support inter-network roaming and mobility.

Table NTN Ecosystem.

Satellite Constellation Operator (SCO)/ Satellite Communication Provider (SCP)	Mobile Network Operator (MNO)/Vendor
SpaceX (Starlink)	T-Mobile, Rogers, KDDI, Softbank, NTT docomo, Optus, etc.
Globalstar	Apple
OneWeb	Orange, Softbank, KDDI
Viasat Skylo Technologies*	Softbank, Deutsche Telekom,Telus, Verizon, Telefónica, Soracom, etc.
Link	Vodafone, Rogers, etc.
SES-Intelsat	Deutsche Telekom, NTT docomo, Reliance Jio, etc.
AST Space Mobile	AT&T, Vodafone, Verizon, Orange, Telefónica, Rakuten, etc.
Amazon (Project Kuiper)	Verizon, Vodafone, NTT docomo, etc.
Omnispace	MTN, Nelco
Echostar Mobile	Swisscom

*: Satellite Service Provider (SSP)

NTN Technology Trends – NTN Platforms –

NTN is a network that provides a communication environment, via wireless communication based on satellites and unmanned aerial vehicles, to areas that cannot be served by terrestrial networks. A variety of platforms are already in use, including satellites in geostationary Earth orbit (GEO), medium Earth orbit (MEO), and low Earth orbit (LEO), as well as aircraft. Within the aircraft category, to commercialize NTNs using High Altitude Platform Stations (HAPS) and Unmanned Aircraft Systems (UAS), demonstration tests are underway to put NTNs into practical use.

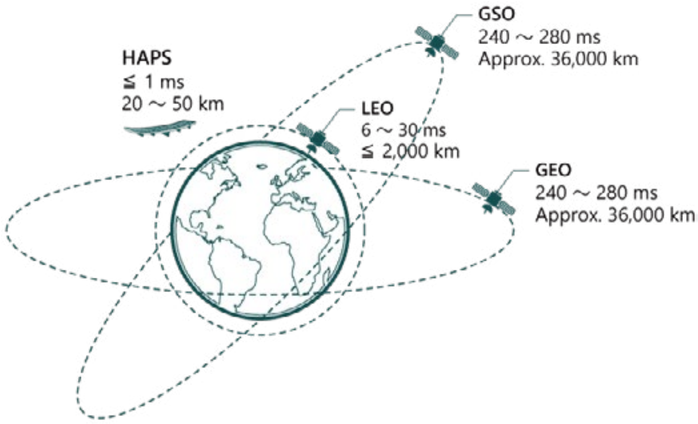


Table NTN Platforms.

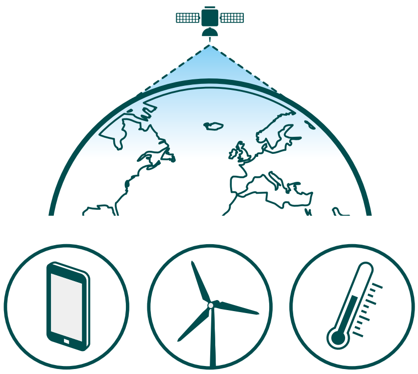
Source: 3GPP TR 38.821 V16.2.0 (2023-03)

Platform	Features	Main Use Cases
Low Earth Orbit (LEO) Satellite	Altitude 300 to 1500 km Ground coverage ranges from 100 to 1000 km. Circular orbit around Earth Low latency The coverage area per satellite is narrower than that of other satellites. Many satellites are required for coverage.	Connections to mountainous and rural areas, etc. International Space Station (ISS), Hubble Space Telescope, telecommunications, etc.
Medium Earth Orbit (MEO) satellites	Altitude 7000 to 25000 km Ground coverage ranges from 100 to 1000 km. Circular orbit around Earth Latency is high due to the higher altitude compared to LEO. Fewer satellites are needed to provide coverage than in LEO.	Global Navigation Satellite Systems (GNSS) include GPS, GLONASS, Galileo, communications, remote sensing, etc.
Geostationary Earth Orbit (GEO) satellites	Located about 36,000 km above the equator Ground coverage ranges from 200 to 3500 km. Circular orbit with an inclination of 0 degrees above the equator Satellite orbital period coincides with Earth's rotation. The satellite is fixed over the same point.	Communication, broadcasting, weather observation, etc.
Geosynchronous Orbit (GSO)	Altitude approx. 36,000 km Ground coverage ranges from 200 to 3500 km. Circular or elliptical orbit around Earth The orbital period of the satellite coincides with Earth's rotational period. No restrictions on orbit inclination or orbit eccentricity Fixed in the vicinity of a specific point in the sky GEO is a type of GSO.	Communications, positioning services such as Quasi-Zenith Satellite MICHIBIKI
High Altitude Platform Station (HAPS)	Operates in the stratosphere at altitudes of 20 to 50 km. Ground coverage ranges from 2 to 200 km. Unmanned platform, Lower latency than LEO Highly maintainable compared to satellites Including balloons and airships	Communication, surveillance, environmental monitoring, etc.
Unmanned Aircraft System (UAS)	Unmanned Aerial Vehicles (UAVs) and drones Drone altitude is limited to 90 to 150 m, depending on country, region, flight area, etc.	Communication, monitoring, delivery, etc. Rapidly deployable in areas hit by natural disasters, etc.

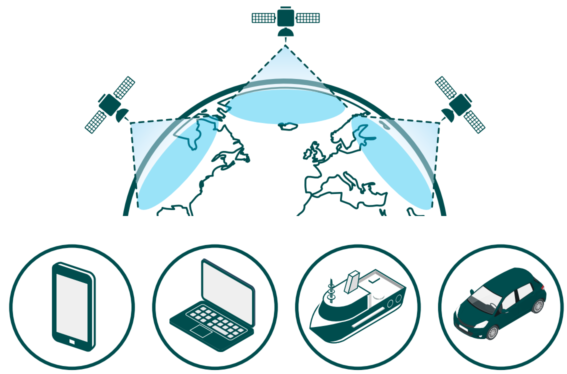
NTN Technology Trends – Technical Specifications –

The NTN technical specifications are currently being discussed within the standards organization – The 3rd Generation Partnership Project (3GPP). 5G NTN standardization began in 2017, with the basic specifications being finalized with Release 17 for 2022.

For NTN, there are two main communication standards as defined by 3GPP:



NTN NB-IoT



NTN NR

NTN NB-IoT

NTN NB-IoT is a communications technology that enables network connections for IoT devices. It is a standard that extends NB-IoT for NTN use and is based on LTE technology. In addition to simple text transmission, the standard supports low data volume communications where long battery life is required and real-time network connectivity is not required, such as for environmental sensors in agriculture and cargo tracking in logistics.

NTN NR

NTN NR is a standard aimed at high-speed communications in areas not covered by terrestrial networks. In addition to sending texts and voice, it is expected to be used for sending data such as images and video.

NTN's expansion features for efficiency and practical application are already being considered even after Release 18 or later.

NTN standardization schedule in 3GPP

NTN Technology Trends – NTN Architecture –

There are two important communication links in the NTN architecture.

Service Link

A service link is a communication link between satellites or HAPS and the user equipment. This allows for extensive communication coverage as it operates independently of terrestrial networks, connecting directly through satellites.

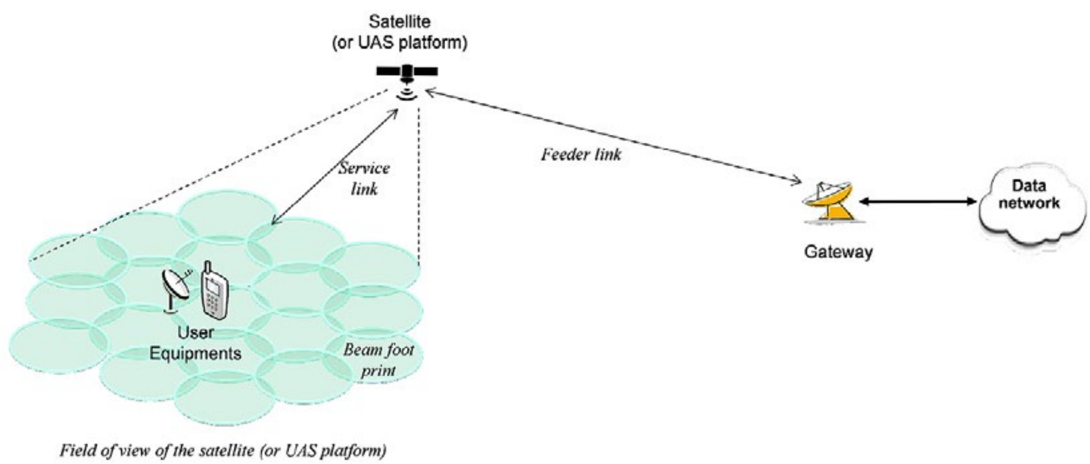
Feeder Link

A feeder link is a communication link between satellites or HAPS and ground stations (gateways).

This link allows satellites to interface with terrestrial networks, making it possible to exchange data with the Internet and other large-scale networks, e.g., ground backbone networks. Communication from satellites to ground stations is called a downlink, while communication from ground stations to satellites is called an uplink.

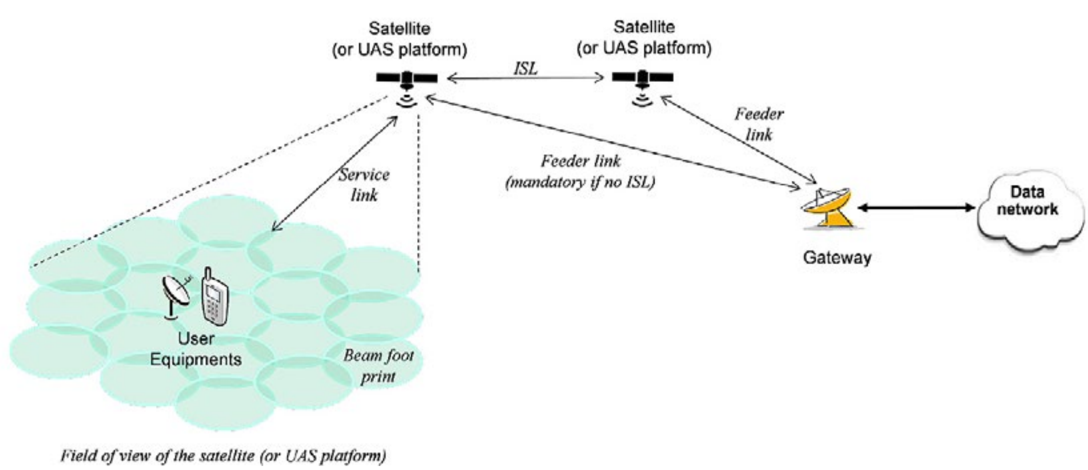
3GPP recommends the adoption of two architectures for the design and deployment of satellite-based NTNs for 5G services.

Transparent Payload – In this architecture, the satellite acts as an analog RF repeater for the feeder and service links. RF filtering, frequency conversion, and amplification are done by the satellite. The result is that the waveform signal repeated by the payload is unchanged. For 5G connectivity, the satellite repeats the 5G NR-Uu radio interface from the feeder link to the service link.



Transparent Payload.

Regenerative Payload – With this architecture, RF filtering, frequency conversion, amplification, demodulation/decoding, switching and/or routing, and coding/modulation are conducted by the satellite. The satellite acts as a gNB or 5G base station in the sky. The signal received from the Earth is regenerated, with the NR-Uu interface operating on the service link, while the N2 and N3 operate over a satellite radio interface on the feeder link.



Regenerative Payload.

NTN Technology Trends – Direct to Device –

Satellite communication services have traditionally required either a fixed ground station with a satellite communication antenna or the inclusion of a satellite communication antenna in the user equipment (UE) like mobile or IoT devices. Recently, however, there has been growing interest in direct communication (Direct to Device: D2D) services between satellites and mobile or IoT devices, without the need for ground stations with satellite communication antennas.

D2D communication offers the advantage that mobile network operators can deliver communication services to disaster-stricken or highly inaccessible areas.

The following introduces the three types of D2D systems.

Proprietary

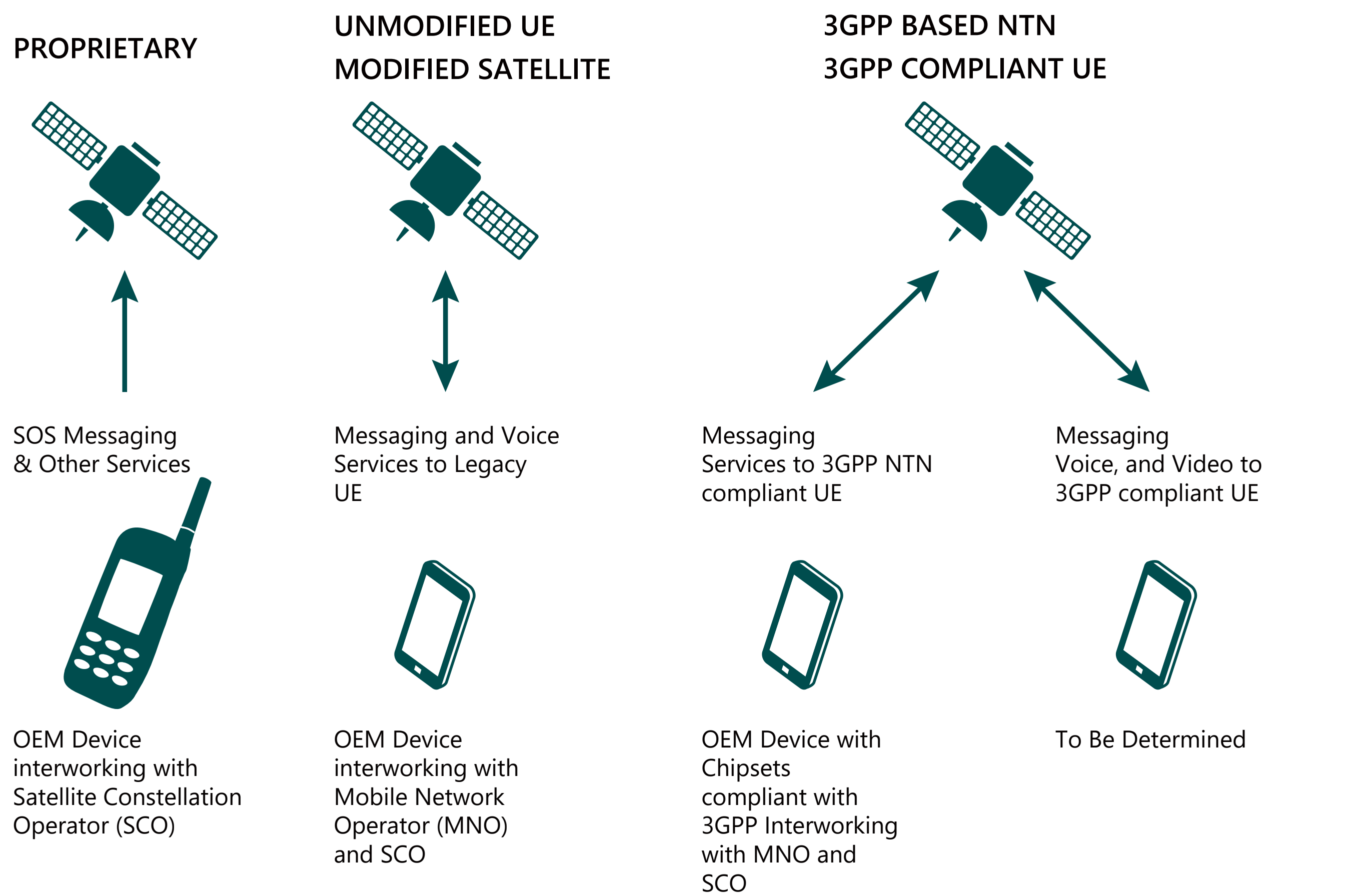
This system uses proprietary communication protocols and technologies developed by telecom operators and equipment manufacturers. Since this is not standardized, it is not interoperable with other operators' NTNs. This utilizes the microwave frequency band used by LEO satellites to establish direct communication between the UE and LEO satellites.

Unmodified UE

This system performs D2D communication using the 4G technology without modifying the communication technologies and protocols for the UE. As such, the satellite needs to support 4G and 5G communication technologies. A feature of this system is its excellent interoperability between different equipment and networks.

3GPP Standard NTN

This system applies the NTN technical specifications from 3GPP Release 17 and beyond to both the UE and satellite, thus facilitating D2D communication. This employs NTN NB-IoT for low-capacity communication and NTN NR for high-speed, high-capacity communication.



NTN Technology Trends – NTN Frequency Allocation –

This section introduces the trends in international frequency allocation for NTN. The ITU-R handles the management and coordination of radio frequencies. The World Radiocommunication Conference (WRC-23), held in December 2023, discussed adjustments to the frequency allocations for NTN and International Mobile Telecommunications (IMT).

Traditional NTN services are classified into Mobile Satellite Services (MSS) and Fixed Satellite Services (FSS). MSS is used for ships, vehicles, or dedicated mobile phones, while FSS is for fixed ground stations, serving satellite communication for homes and businesses. NTNs will now support communication via mobile terminals.

Frequency allocations are divided into primary and secondary services. Primary services refer to major operations such as satellite communication, mobile communication, and radio astronomy that use the designated frequency. These services are protected from interference by both primary and secondary services. On the other hand, secondary services need to avoid causing harmful interference to the primary services and cannot claim protection from interference from primary services.

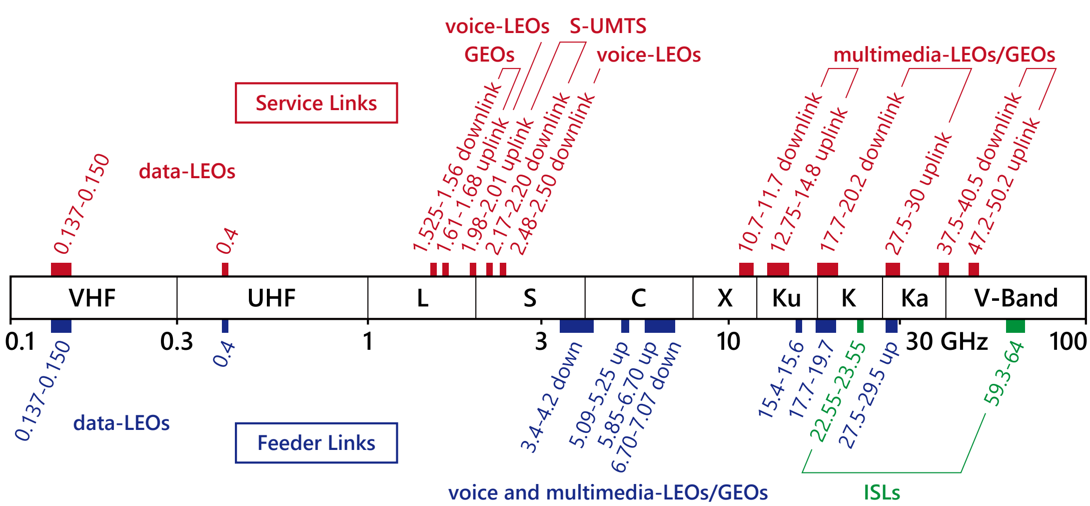
- **Primary frequency**: This frequency plays a crucial role in NTN communication, and some frequency bands can be used similarly to traditional MSS and FSS communication.
- **Secondary frequency**: As mentioned earlier, since protection against interference cannot be required, it is necessary to consider issues such as interference with other communication services.

Frequency band usage is categorized as follows.

- **Lower frequency band (Sub6)**:
  This frequency band is mainly utilized for MSS purposes. This band is narrow and suitable for emergencies and communications mainly focused on messages and voice calls. The application of communication between satellites and ground cellular networks is increasing.
- **Higher frequency band (>10 GHz)**:
  This frequency band is mainly utilized for FSS purposes. Ground terminals using these bands have high-performance antennas, making them excellent for high-capacity data transmission and therefore capable of providing broadband services. Meanwhile, the implementation of satellite-to-cellular communication in this frequency band is still developing.

Additionally, there are dedicated frequency bands for data communication between satellites. This link supports inter-satellite communication and enables wide-area coverage. The frequencies used for NTN communication are expected to increase in the future (e.g., WRC-27).

NTN band	Uplink (MHz)	Downlink (MHz)	Mode	Channel Bandwidth (MHz)
n253 extension	1663-1675	1518-1525	FDO	3, 5, 10
n254 (L+S)	1610-1626.5	2483.5-2500	FDO	5, 10, 15
n255 (L)	1626.5-1660.5	1525-1559	FDO	5, 10, 15, 20, 30
n256 (S)	1980-2010	2170-2200	FDO	5, 10, 15, 20, 30
n510	27500-28350	17300-20200	FDO	50, 100, 200, 400
n511	28350-30000	17300-20200	FDO	50, 100, 200, 400
n512	27500-28350	17300-20200	FDO	50, 100, 200, 400



Anritsu NTN Test Solutions (1/2)

Research & Development

ME7869A

ME7838 series

Transmission characteristic, group delay, return loss of devices and materials

MS46122B

Material measurement

MT8862A

Wireless LAN RF performance Test

MG362x1A

Signal source for device and antenna evaluation

ME7834NR

5G NR mobile devices test

ME7873NR

New Radio RF conformance test

Development & Production for Chipset and Devices

MT8821C

3G/4G device development

MD8430A

4G protocol test

MT8000A

5G protocol test, RF measurement

MT8870A

RF measurement (production)

Optical Communications

MS9740B

Optical wavelength, power

MP2110A

Waveform evaluation, bit error rate

MP1900A

Transmission quality of digital signals

ME7848A

Transmission characteristic of optical devices

Measurement & Monitoring for Radio Conditions

MS2090A

Real-time spectrum measurement

MS276xA

Spectrum measurement

MS2720xA

Spectrum monitoring

MS2840A/MS2850A

Spectrum measurement

Network Performance

MT1000A/MT1040A

Latency measurement

Anritsu NTN Test Solutions (2/2)

Process	Test Subjects	Exam Content	Measuring Instruments	Page
R&D	Chipset/Cellular	Protocol, RF performance	Signaling Tester	10
	FWA/CPE	RF parametric testing	RF Tester Wireless LAN Tester	12
	Phased Array Antenna	Radiation pattern	Network Analyzer Spectrum Analyzer Signal Generator	13
	Millimeter Wave, Microwave Modules/Components	Transmission/reflection characteristics, impedance	Network Analyzer	15
	Millimeter Wave Materials	Dielectric constant and dielectric loss measurement	Network Analyzer	17
	Inter-Satellite and Satellite-to-Ground Optical Communication Modules	Light source output characteristics	Optical Spectrum Analyzer	18
		Digital signal quality Bit error rate Eye pattern	Signal Quality Analyzer Bit Error Tester Oscilloscope	19
		E/O, O/E, O/O characteristics of optical communication modules	Network Analyzer	20
Installation and Maintenance	Ground Station	Jamming and interference detection	Handheld Spectrum analyzer	21
	Spectrum Monitoring	Jamming waves, interference waves, and wanted waves monitoring	Spectrum Analyzer	24
	NTN Communication Latency	Throughput and delay measurement	Field Transport Tester	25
	NTN and Terrestrial Networks	Throughput and delay measurement	Field Transport Tester	26
	Automotive	Throughput and delay measurement	Field Transport Tester	27

Chipset/Mobile 3GPP Testing (1/2)

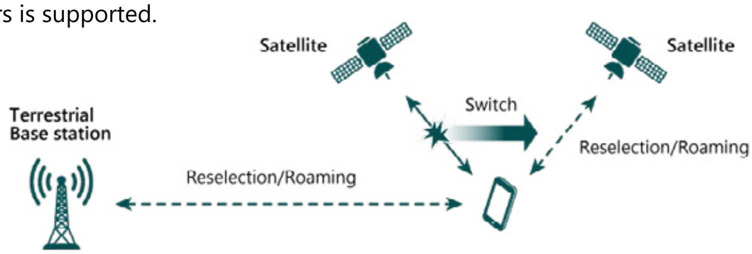
Technical Issues

With NTN, when communicating between satellites or between a satellite and the ground, in addition to radio wave propagation delay, Doppler shift, which changes the radio frequency, can occur. Doppler shift can be calculated from the relative speed and radio frequency between a satellite and a base station. This Doppler shift is most noticeable with LEO satellites, since their relative speed is larger than that of other orbit satellites. To perform correction for this Doppler shift, it is essential to know the moving speed and position of both the base station or IoT device and the satellite.

Reselection is also performed between the NTN and terrestrial networks, switching between the two networks while monitoring the difference in the radio wave reception strength. Here, NTN's reselection is performed not only based on differences in the radio wave reception strength, as is the case with terrestrial networks, but also varies with the precise location information of the satellites and communication terminals. This makes the operation more complicated than reselection with terrestrial networks. In addition, satellite communications easily cross borders, such that roaming occurs, such as from an NTN operator to a TN operator. Therefore, when developing an NTN-compatible communications terminal, it is necessary to check the roaming operation following the 3GPP standard so that roaming between carriers is supported.

Problem-Solving Solutions

- IoT/Mobile Terminal RF Testing, Protocol Testing
- Simulation of NTN and terrestrial networks
- RF testing in an OTA environment



Testing Solutions

Anritsu provides 3GPP-compliant protocol tests and RF TRx Testing Solutions for NTN NB-IoT devices. We will continue to enhance our testing functions to help overcome problems associated with NTNs and improve verification efficiency.

RF Transmitter/Receiver Test

Anritsu's RF TRx test solution provides a TRx test environment that is compliant with the 3GPP standards to ensure stable communications for NTN IoT devices and mobile terminals. Simple operation and flexible parameter settings enable the efficient implementation of RF Tx/ Rx tests.

Radio Communication Test Station
MT8000A

Equipped with 5G pseudo base station functionality, it performs RF and protocol tests from FR1 (up to 7.125 GHz) to FR2 (mmWave band)

Radio Communication Analyzer
MT8821C

RF transmission and reception testing for the development of communication terminals such as smartphones and IoT modules

Universal Wireless Test Set
MT8870A

Mass production measuring instrument for communication devices compatible with various wireless standards such as 5G NR sub-6 GHz, NB-IoT, and wireless LAN

Product details here

Chipset/Mobile 3GPP Testing (2/2)

Protocol Testing

To accurately evaluate the protocols implemented in NTN-compatible chipsets and modules, it is necessary to set up a variety of test cases, such as simulation under various propagation delay conditions and roaming between NTN and terrestrial networks, in addition to reproducing the satellite connection environment. Anritsu's Signalling Tester MD8430A supports the rapid creation and evaluation of these test cases, enabling the efficient development and performance verification of chipsets and modules.

Radio Communication Test Station
MT8000A

Equipped with 5G pseudo base station functionality, it performs RF and protocol tests from FR1 (up to 7.125 GHz) to FR2 (mmWave band)

Signaling Tester
MD8430A

A base station simulator that enables service and communication function testing of LTE-compatible multi-system terminals, including smartphones, all in one device

Universal Wireless Test Set
MT8870A

Mass production measuring instrument for communication devices compatible with various wireless standards such as 5G NR sub-6 GHz, NB-IoT, and wireless LAN

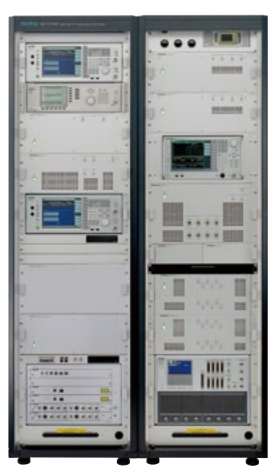
Product details here

Conformance Testing

To ensure the quality of NTN-compatible IoT devices and mobile terminals, conformance testing that complies with the latest 3GPP standards is required. Anritsu's 5G NR Mobile Device Test Platform ME7834NR and New Radio RF Conformance Test System ME7873NR provide timely 3GPP-compliant test cases that satisfy customer expectations, accelerating the time to market for customers' products.

5G NR Mobile Devices
Test Platform
ME7834NR

3GPP-compliant protocol conformance and carrier acceptance test platform for mobile devices supporting multiple radio access technologies



New Radio RF Conformance
Test Systems
ME7873NR

Compliant with 3GPP standards, it supports both FR1 and FR2 frequency bands.
Also, the test platform is GCF and PTCRB certified.

FWA/CPE RF Performance Test

Industry Issues

Fixed wireless access (FWA) is becoming more widely used in areas where it is difficult to lay optical fiber networks. FWA is used for the last mile from the mobile network base station to the user's premises. If any issue occurs at the base station, FWA communications will become unstable. To address these issues, studies are being conducted to improve communication stability, mainly by providing redundancy to network functions through the combined use of mobile networks and an NTN. The same applies to customer premises equipment (CPE).

Communications module vendors typically guarantee that their modules comply with the 3GPP and IEEE 802.11 standards. However, depending on the design of the FWA (CPE) equipment, the RF characteristics may deteriorate and degrade due to the construction of the product and the internal arrangement of the power supplies, electrical components, and other RF devices.

Problems-Solving Solutions

• RF Parametric Testing

Testing Solutions

To verify the wireless communication quality of FWA and CPE, Anritsu recommends that the following tests be performed:

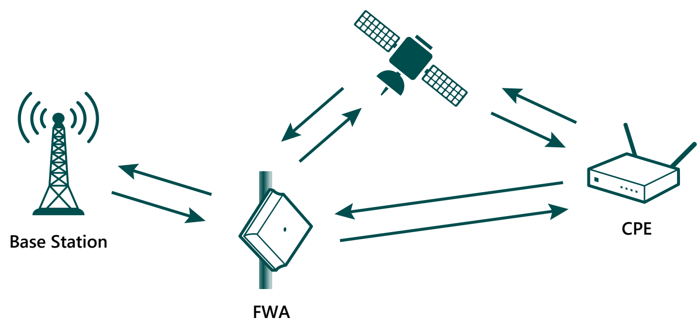
RF TRx Testing

• 5G NR 3GPP Testing

• Wireless LAN IEEE 802.11

Application Testing

IP Throughput Test



Product details here

Radio Communication
Test Station
MT8000A

Equipped with 5G pseudo base station functionality, it performs RF and protocol tests from FR1 (up to 7.125 GHz) to FR2 (mmWave band).

Radio Communication
Analyzer
MT8821C

RF transmission and reception testing for the development of communication terminals such as smartphones and IoT modules

Wireless Connectivity
Test Set
MT8862A

Wireless LAN IEEE 802.11a/b/ RF transmission and reception tests for g/n/ac/ax/be (2.4 GHz, 5 GHz, 6 GHz) compatible devices

Universal Wireless
Test Set
MT8870A

Mass production measuring instrument for communication devices compatible with various wireless standards such as 5G NR sub-6 GHz, NB-IoT, and wireless LAN

Product details here

Large Phased Array Antenna RF Characterization (1/2)

Technical Issues

A phased-array antenna consists of multiple antenna elements in a matrix with which beamforming and directionality are precisely controlled with the phase of each element and synthesizing the radiation pattern. To maximize the performance of a phased-array antenna, it is necessary to verify that the control of the radio wave strength, phase, and other aspects of each element is functioning as expected.

Problem-Solving Solutions

- Verification of large-array antennas
- Conversion of near field to far field and determination of radiation characteristics

Evaluation in the far field requires a long-distance and wide-area test system and space.

On the other hand, the amplitude and phase information of the measured near-field radio waves can be converted to far-field information. In this case, the test system and space required are kept small. However, when the coaxial or other cables used for testing are long, the phase shift is likely to occur, raising concerns that errors will increase when converting from the near field to the far field.

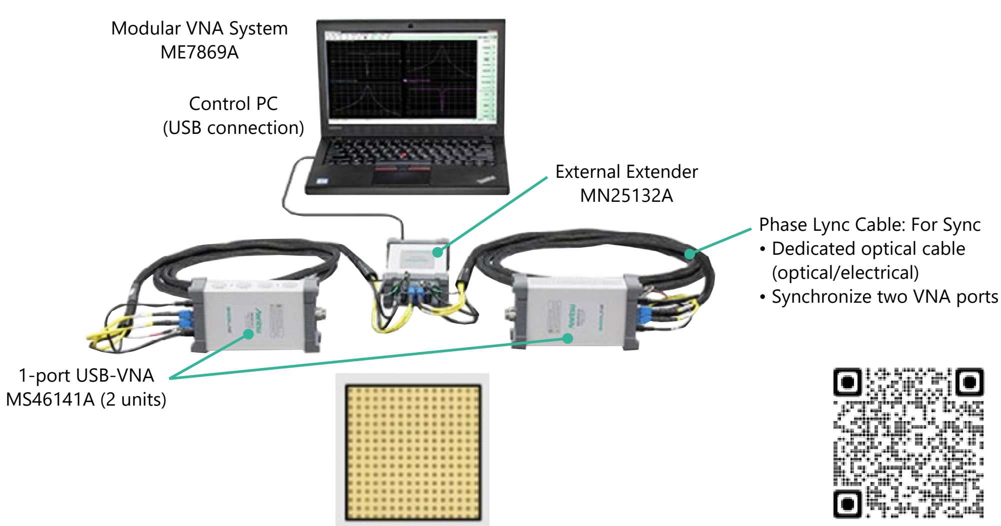
Testing Solutions

Radiation Pattern (Near-field) Evaluation Solution for Large Array Antennas

For those users who are concerned about measurement errors caused by test cables, Anritsu recommends the use of the Modular Vector Network Analyzer (VNA) System ME7869A, which has two independent VNA ports.

Features

- Two independent VNA ports allow flexible installation close to the device under test
- By connecting the VNA port with a dedicated optical cable (PhaseLync, optical/electrical), which is less prone to phase shift, the phase error is suppressed.
- Even if the two VNA ports are separated, the transmission characteristics can be evaluated using vectors (amplitude and phase)
- Easier evaluation of large-array antennas



Phased Array Antenna

Product details here

Reference: For a typical VNA

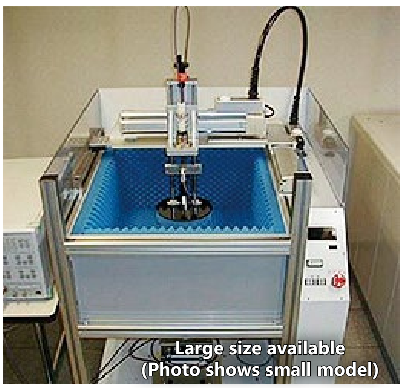
- The terminal (measurement port) is fixed to the surface of the measuring instrument.
- It is necessary to extend the coaxial cable to the object to be measured and set up the measurement system so that, as far as is possible, the coaxial cable does not move.
- When evaluating a large-array antenna, the coaxial cable must be several meters long.
- Phase shift occurs when the coaxial cable moves during measurement.
- When the phase changes, the standing wave conditions inside the cable change, and the amplitude also fluctuates. This is a result of measurement error factors.

Large Phased Array Antenna RF Characterization (2/2)

Modular VNA System ME7869A (Anritsu) and Flat Antenna Scanner (Tokai Techno Co., Ltd.)
Near-field Antenna Measurement System Combining

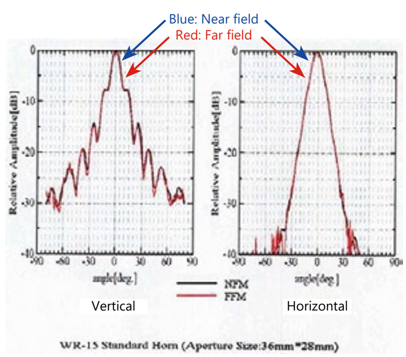
Features

- Horizontal scan: The measuring antenna and the receiving antenna are placed parallel to each other. No vertical installation space is required
- Large flat antenna scanner: Supports large array antennas up to several meters across
- Near-field/far-field transformation algorithm: The far-field pattern can be calculated from the near-field amplitude and phase. High correlation achieved by algorithm (Anritsu)



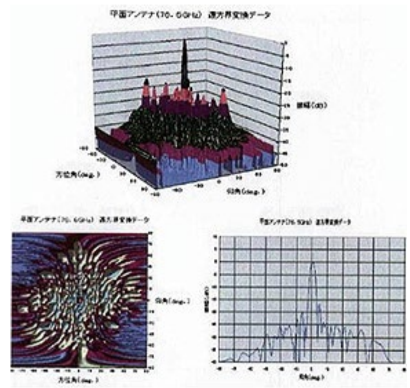
Planar Antenna Scanner

- Horizontal scan method
- Supports large array antennas



Near field/far field data comparison

- Highly correlated data can be obtained between the near field (blue line) and far field (red line)



Example of planar antenna far-field conversion data

- Absolute gain, polarization, and 2D pattern can be measured and evaluated.

Exhibitor (three images above): Tokai Techno Co., Ltd.

[High Points]

□ **Horizontal scan method**: The measuring antenna and receiving antenna are placed parallel to each other above and below the object to be measured. This is possible because the VNA is small and lightweight.

□ **Large planar antenna scanner**: The photo shows a small antenna, but in the case of large array antennas, we have experience with units that are several meters across (e.g. 7 m × 1 m). The receiving antenna and module move back and forth and side to side like a crane grabber game, but no phase shift occurs because the phase is corrected by a dedicated optical cable. The final measuring end is connected to the antenna with a short cable, which is fixed in place so that it does not move.

□ **Algorithm**: The conversion algorithm is key to the efficacy of the system. Based on amplitude/phase data in the near field, radiation patterns that correlate with the far field can be calculated. The blue and red graphs almost overlap, indicating a correlation. In addition, Tokai Techno's system allows you to set the distance and interval to be plotted according to the wavelength to be measured, and can perform automatic measurements, as well as verify absolute gain, polarization, 2D patterns, and other far-field conversion data on graphs.

□ **Disadvantages of far field**: When measuring several meters away from the antenna, the measurement range becomes quite large. This requires an evaluation environment such as a large anechoic chamber, such that the total construction costs for the building becomes prohibitive. Additionally, as the frequency increases, so too does attenuation that occurs as the frequency propagates through space. As a result, there are cases where the side lobes (the tails of the graph) are buried in noise preventing the determination of the characteristics.

□ **Advantages of near field**: Since the measurement port and the object being measured are close to each other, the output can be suppressed. Therefore, the radio wave absorber of the flat antenna scanner is sufficient, so that a large-scale radio wave anechoic chamber is not required. Furthermore, since measurements can be taken on a flat surface, there is no need to consider the height of the installation location. In addition, since it is converted from near-field data, the "side lobe (tail of the graph)" characteristics can also be confirmed.

Millimeter Wave Component/Device Characteristic Evaluation

Technical Issues

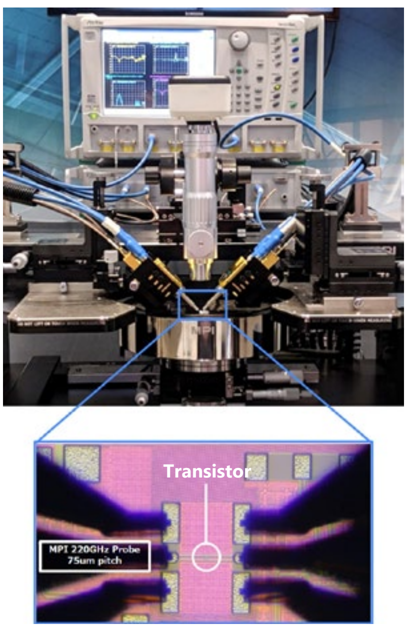
In the millimeter wave band, conductor losses and insulation losses increase with the frequency. This results in greater signal attenuation and less efficient communication. In addition, the device size is smaller than that of microwave devices, making miniaturization and integration difficult, requiring ingenuity to develop packaging and board design. For this reason, it is necessary to test the characteristics such as transmission loss, gain, and bandwidth to verify that the device maintains its designed performance.

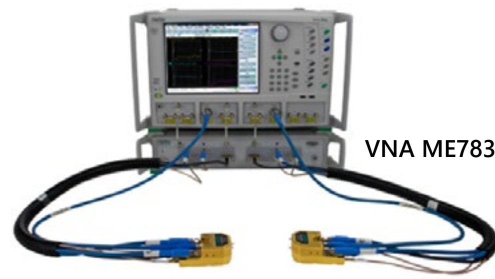
Problem-Solving Solutions

- S-parameter evaluation of mm-wave components/devices
- Multiple bands can be measured simultaneously with one system

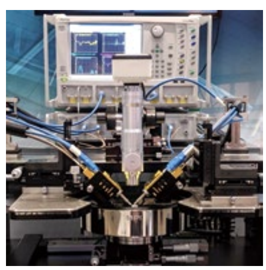
Testing Solutions

Vector network analyzers (VNAs) are essential for evaluating the characteristics of millimeter wave boards, components, devices, etc., such as transmission, reflection, and S-parameters.

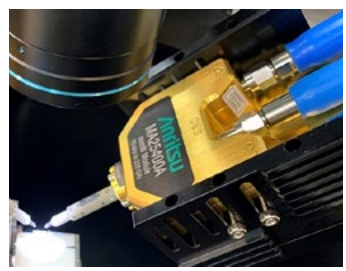




VNA ME7838G



MPI Probe Station

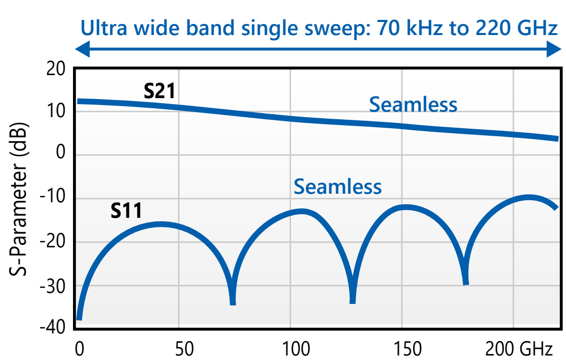


Dedicated probe tip
(MA25400A + probe tip)

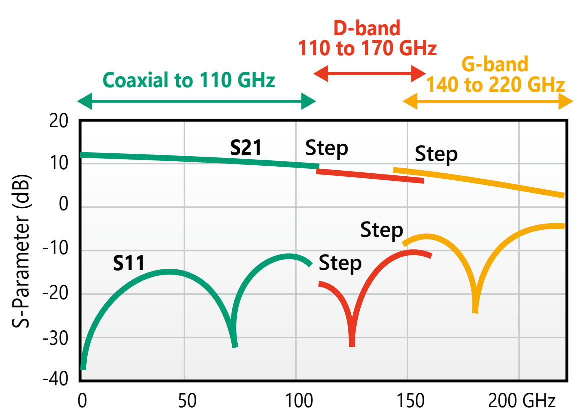
Product details here

Features

- Can simultaneously measure frequency ranges from 70 kHz to 220 GHz.
- There is no need to replace waveguide modules, so there are no data splices and no gaps.



Reference:
Conventional measurement method



Millimeter Wave Component/Device Characteristic Evaluation Probe

Anritsu probes are small and lightweight, making it possible to build a space-saving, compact probe measurement system. Probe stations, probe tips, and calibration boards can be selected to suit your application.

Probe station (example)

Probe tip: Coaxial connector
□ 110 GHz, 1 mm

Wideband Model
70 kHz to 125 GHz
• Wideband VNA ME7838AX
• Millimeter wave module 3743AX
(1 mm connector)

Probe tip: Waveguide
□ 110 GHz to 170 GHz, WR-6

110 GHz to 170 GHz
• VNA MS4644B/MS4647B
• Test Set 3739C
• Millimeter Waveguide Extender Module
(WR-6.5)

Probe tip: 0.6 mm coaxial interface
□ Up to 220 GHz, 0.6 mm

Wideband Model
70 kHz to 220 GHz
• Wideband VNA ME7838G
• Millimeter wave module MA25400A
(0.6 mm connector)

Probe tip: Waveguide
□ 220 GHz to 325 GHz, WR-3.4

220 GHz to 330 GHz
• VNA MS4644B/MS4647B
• Test Set 3739C
• Millimeter Waveguide Extender Module
(WR-3.4)

Dielectric Constant Measurement for Millimeter Wave Materials

Technical Issues

The millimeter waves used in communications between NTN satellites and ground stations have characteristics of easy attenuation and a high degree of directivity. In particular, attenuation is significant in the 28-GHz band due to water droplets caused by rain or condensation. Therefore, wireless communication devices such as antennas that are installed outdoors require water-repellent paints and/or materials that prevent water droplets from adhering. At the same time, the performance of communications equipment must be ensured, so creating a dielectric material that satisfies both performance requirements has become a challenge.

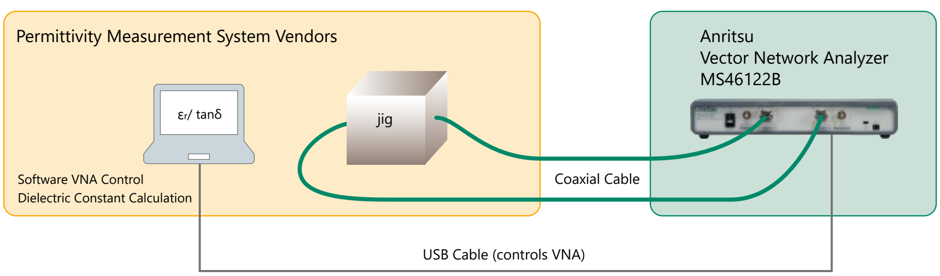
Problem-Solving Solutions

• Dielectric constant and dielectric loss measurement for millimeter wave materials
• Use of measuring fixtures according to the shape of materials, including thin films, substrate materials, and paints

Testing Solutions

The dielectric constant of millimeter wave materials can be measured using the following configuration.
(1) Vector Network Analyzer
(2) Dielectric constant measurement fixture: Used to hold a sample of the material to be measured
(3) Dielectric constant measurement software: Automatically controls the VNA and measures the frequency characteristics of the sample.

The dielectric constant and dielectric tangent of the sample are calculated based on the measurement data.
Fixtures and software are supplied by the dielectric measurement system vendor, while the VNA is provided by Anritsu



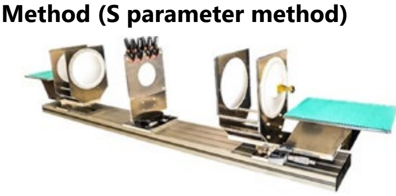
Product details here

The optimum dielectric constant measurement tool is selected according to the type and shape of the sample and the measurement conditions.

TM Cavity Resonance Method

Sample to be Tested	Silica and other powders, battery materials, films, Ceramics, resins, liquids, etc.
Measurement Frequency	200 MHz to 10 GHz (single-point measurement) 300 MHz, 1, 2, 2.45, 3, 5, 5.8, 10 GHz
Dielectric Constant	Measurement range: 1 to 150 Repeatability: ±1%
Dielectric Tangent	Measurement range: 0.0001 to 0.05 Repeatability: ±3%
Features	High accuracy allows accurate measurement of powder as well as resin Capable of measuring films and low-loss liquids

Free Space Method (S parameter method)



Sample to be Tested	Paints, multi-layers, adhesives, liquids
Measurement Frequency	18 GHz to 170 GHz
Dielectric Constant	Measurement range: 2 to 200 Repeatability: Depends on the accuracy of the VNA since the fixture does not move Actual accuracy guideline: ±10%
Dielectric Tangent	Measurement range: 0.01 to 20 Repeatability: The fixture does not move, so the VNA accuracy is reflected Actual accuracy guideline: ±20%
Sample Size	@18 GHz 150 mm × 150 mm or larger @76.5 GHz 80 mm × 80 mm or larger
Features	Measurements can be made in free space, no anechoic chamber is required Suitable for samples that cannot be cut and thick materials

Optical Communication at NTN – Optical Module Performance Evaluation

Technical Issues

Optical communication between satellites or between satellites and ground stations is attracting attention as a next-generation communications infrastructure. Optical frequency bands are outside the scope of the Radio Regulation and do not require a license, and are expected to enable faster, larger-capacity, and lower-latency communications than radio waves. Starlink already uses inter-satellite optical communications. Additionally, demonstration experiments are also underway on a portable optical ground station that is small and easy to carry. In the future, it may be possible to install portable optical ground stations closer to ordinary users.
The optical transceiver modules installed in satellites and ground stations incorporate a light source, optical amplifier, and transceiver signal processor. To ensure the quality of optical communications even in the harsh environment of space, it is important to verify the physical characteristics of the light sources and optical amplifiers.

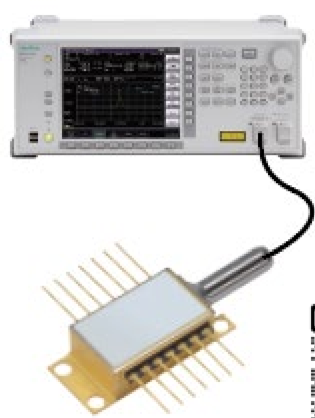
Testing solutions that solve your problems

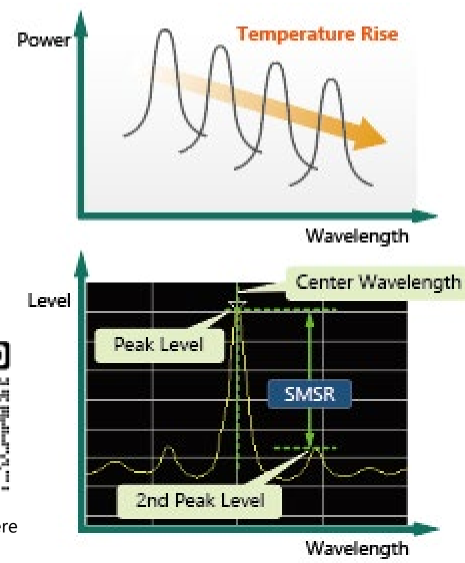
- Light source output power, wavelength stability
- Noise characteristics and amplification characteristics of optical amplifiers

Testing Solutions

Light Source Characteristics

The output characteristics of the light source can be evaluated using the Optical Spectrum Analyzer MS9740B.
This unit also supports the evaluation of 1550-nm light sources, which are becoming the de facto standard for inter-satellite optical communications. Users can verify the output power, wavelength, side-mode suppression ratio (SMSR), optical signal-to-noise ratio (OSNR), etc. of the light source.

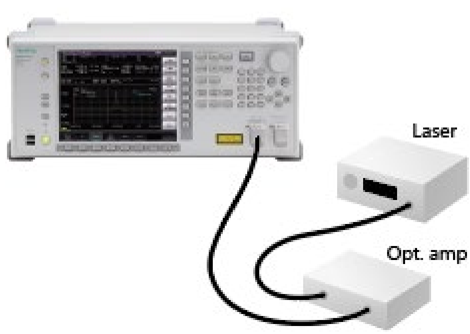


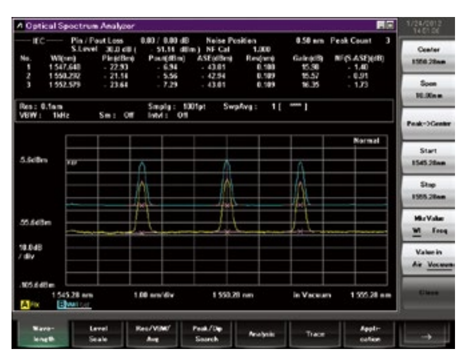


Product details here

Characteristics of Optical Amplifiers

The MS9740B can also evaluate the NF and gain of EDFAs used for optical communications. In addition to the ASE interpolation method using noise fitting, the polarization nulling and pulse methods are also supported.





Optical Communication at NTN – Signal Quality Evaluation of Optical Modules (1/2)

Technical Issues

Progress is being made toward the practical realization of optical communications between satellites and between satellites and ground stations. For example, in Japan, as of 2024, communication speeds of approximately 1.8 Gbps have been achieved between satellites located approximately 40,000 km apart. Starlink is already operating 100-Gbps optical communications between its LEO satellites. An increase in NTN communication capacity is anticipated for the future, such that research and development into achieving even higher speeds and higher-capacity communications is ongoing.

Optical communication modules consist of multiple components, including chips, electrical/optical wiring, and connectors. The development and design of these devices is achieved through the R&D process, which includes prototyping, debugging, and design verification. As part of these processes, engineers must repeatedly evaluate and improve the transmission and reception characteristics of the optical communications module to minimize the degradation of high-speed digital signals and ensure sufficient operating margins.

Problem-Solving Solutions

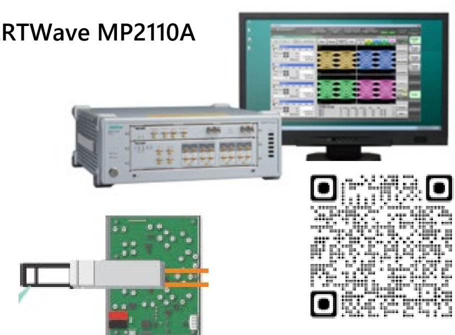
• Digital signal waveform and eye opening of optical communication modules
• Operating margins such as bit error rate and jitter tolerance

Testing Solutions

Evaluation of Digital Signal Waveforms

Anritsu's sampling oscilloscope BERTWave MP2110A performs eye-pattern analysis of digital signal waveforms and can evaluate the amplitude, jitter, and skew (time difference) of each eye.

BERTWave MP2110A



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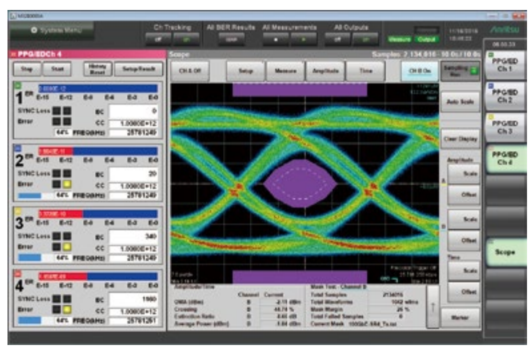
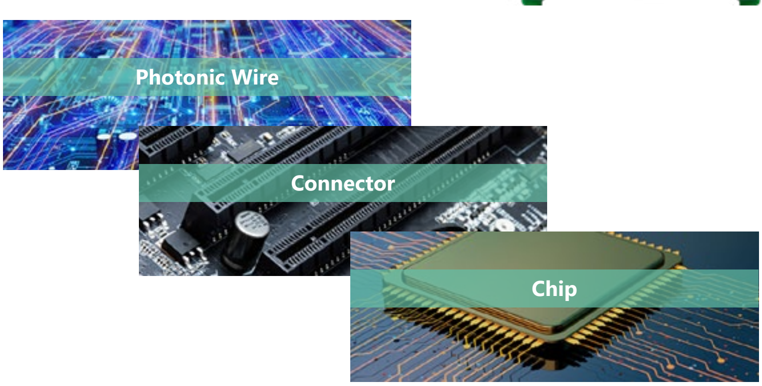
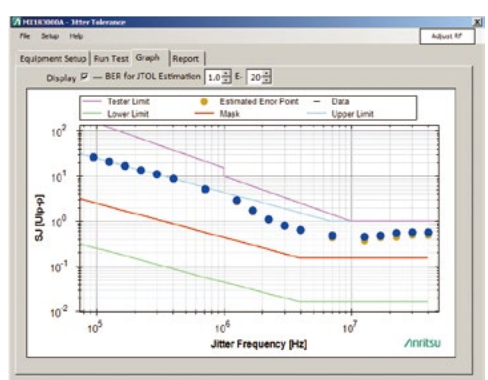


Furthermore, by using the Signal Quality Analyzer-R MP1900A, which has a signal generation (PPG) function and bit error rate measurement function, it is possible to apply noise, jitter, and other stresses to the digital signal to evaluate the jitter tolerance, crosstalk, operating margin, and other characteristics of USB devices.

Signal Quality Analyzer-R MP1900A

Product details here





Optical Communication at NTN – Signal Quality Evaluation of Optical Modules (2/2)

Problem-Solving Solutions

- Measurement of insertion loss and reflection of components and signal lines in optical communication modules
- Identifying the cause of signal degradation in optical communication modules

Testing Solutions

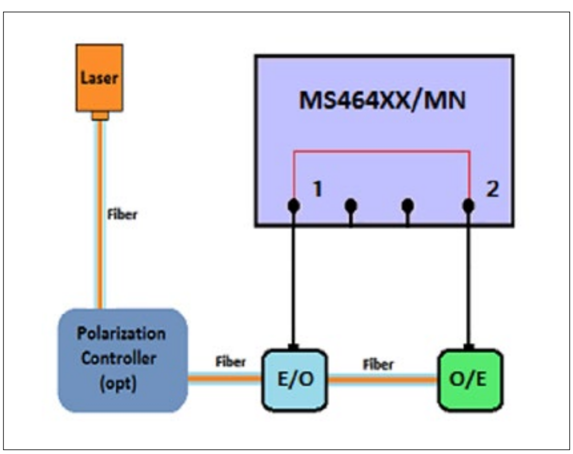
Anritsu's Optoelectronic Network Analyzer ME7848A can evaluate the insertion loss, reflection characteristics, and optical delay of optical communication modules. By using an E/O converter that converts electrical signals into optical signals and an O/E converter that converts optical signals into electrical signals, it is possible to verify the E/O, O/E, and O/O characteristics of optical communication modules for optical wavelengths of 850, 1310, and 1550 nm.

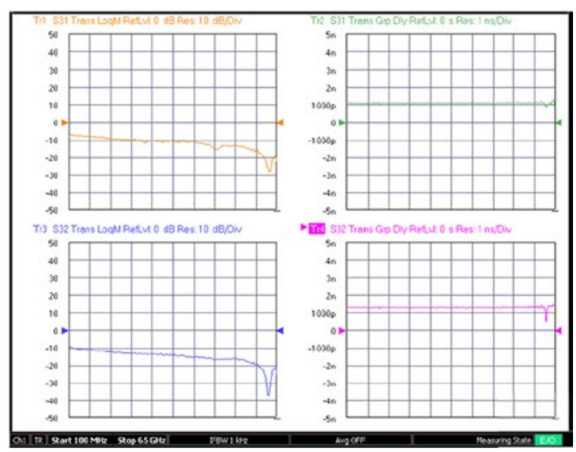
ONA
ME7848A

E/O Converter
MN4775A

O/E Calibration Module
MN4765B

Product details here





Interference Hunting at NTN Ground Stations (1/3)

Technical Issues

According to a survey by the Satellite Interference Reduction Group (SIRG), more than half of the more than 500 satellite operators reported experiencing radio interference at least once a month, with 17% experiencing radio interference on an ongoing basis during their daily operations. The interference stems from the radio waves of 5G terrestrial networks and so on, interferes the ground station communication.

Jamming and interference waves can slow down NTN communication speeds and cause communication errors and, in the worst-case scenario, even cause a complete cutoff of communication. To avoid these situations, it is necessary to check for the presence of jamming or interference waves and, if there are any unwanted radio waves, locate their source and remove them.

Examples of jamming and interference waves

- Emissions from other sources (such as 5G cellular) that are stronger than satellite signals
- Radio interference from aircraft
- Radio interference from high-power radar
- Other sources of interference affecting satellite ground stations
- Spurious or out-of-band unwanted emissions from other satellite ground stations

Problem-Solving Solutions

- Identifying the presence and source of jamming and interference signals through spectrum measurement
- Outdoor and indoor unwanted-signal-strength mapping

Testing Solutions

Anritsu's portable spectrum analyzers are ideal for searching for jamming and interference waves.

Field Master Pro
MS2090A

Spectrum Master
MS276xA

Product details here

<u>Three steps to detect jamming and interference signals</u>

Step 1: Identify the presence of jamming or interference waves

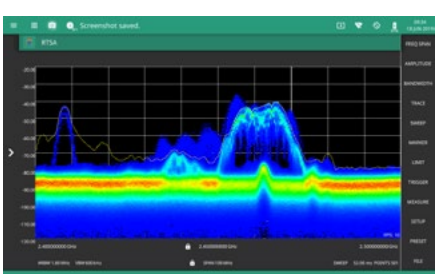
- Real-time measurement captures frequency, power, and occurrence frequency of these unwanted waves.
- Instantaneous/burst changes can also be observed

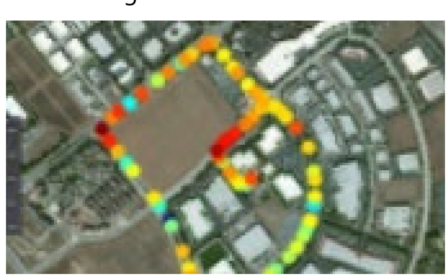
Step 2: Estimating the area where unwanted radio waves are generated

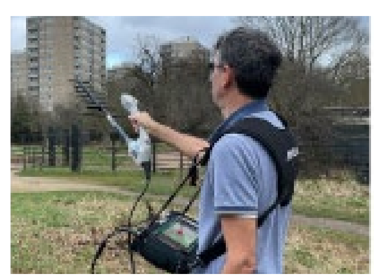
- Measure the surrounding radio wave environment
- By mapping the strength of unwanted radio waves on a map, you can narrow down the areas where unwanted radio waves are generated.

Step 3: Identifying the source of unwanted radio waves

- Spectrum analyzer and portable Utilizing a directional antenna, Identifying the source of unwanted radio waves





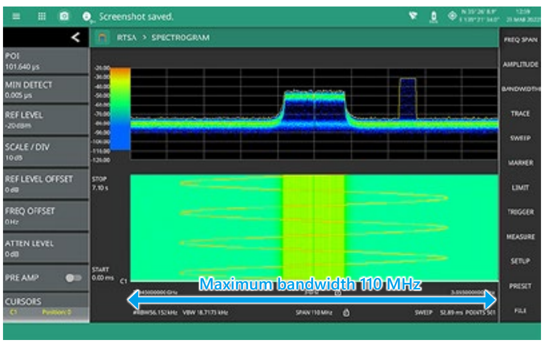


Interference Hunting at NTN Ground Stations (2/3)

To estimate the area being affected by jamming and interference waves and to identify their source, Anritsu recommends using a directional antenna and a polar meter, which can determine the direction of the source of the radio waves.

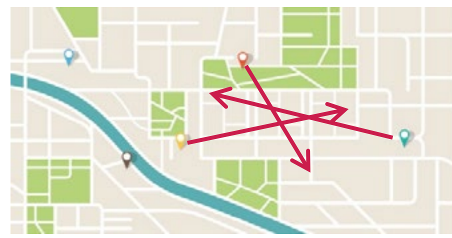
- When the MS2090A detects an unwanted signal, it beeps.
- The pitch and volume of the sound emitted by the MS2090A changes according to the detected signal strength.
- Determination of signal strength by sound without the need to check the MS2090A screen

Field Master Pro MS2090A



Measurements were taken from three or more locations at some distance apart.
You can narrow down the area where jamming/interference signals are occurring.

Check the direction of jamming/interference waves from the measurement point



The source of the noise can be estimated from the measurement point (latitude and longitude) and direction on the map.

■ When searching for unwanted radio waves with frequencies ≤ 6 GHz

Interference Hunter MA2700A

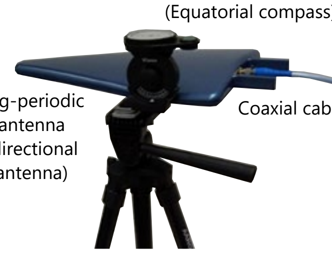
Product details here

■ When searching for unwanted radio waves with frequencies ≥ 6 GHz

We recommend using a commercially available directional antenna and a polar meter.

Polar Meter (Equatorial compass)

Log-periodic antenna (directional antenna)



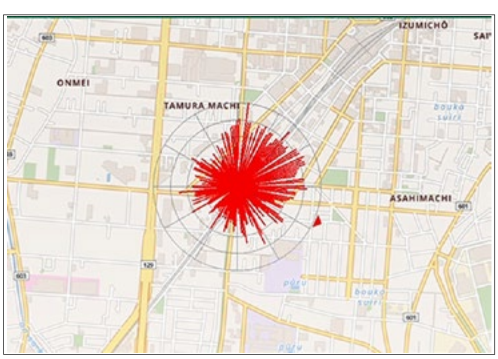
Coaxial cable

Tripod

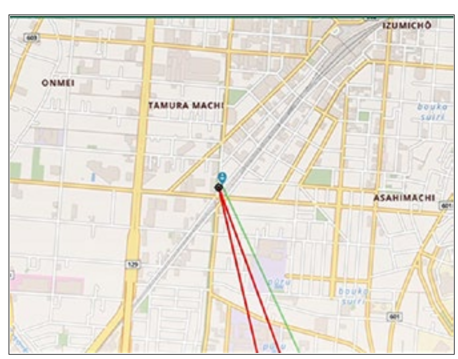
By combining the Interference Finder and Hunter, you can see areas of high signal strength on a map.
The Interference Hunter has a built-in electronic compass, and the direction finding function works in conjunction with the MS2090A main unit.

Polar screen: Illustrates how the signal strength varies with direction. This is useful for determining the direction where the signal is strongest.

Map screen: Once the Polar screen has indicated the approximate direction where the signal is strongest, the Map screen is used to identify the direction more precisely. The green line indicates the direction in which the antenna is pointing. When you press the Hunter's trigger switch for that direction where the radio signals are strongest, it will be recorded with a red line. By performing similar measurements from several locations (e.g. three locations) some distance apart, the source of the interference can be identified.



Polar screen



Map screen

Interference Hunting at NTN Ground Stations (3/3)

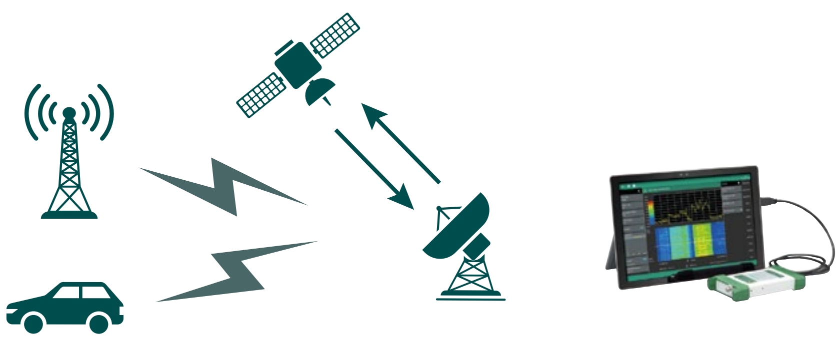
For locating jammers and interference in the microwave to millimeter wave range, a pocket-sized spectrum analyzer is another option.

Spectrum Master
MS276xA

The Spectrum Master MS276xA is extremely compact and lightweight, weighing just 255 g.

- Allows for one-handed measurement of radio waves in the air
- Can be mounted on small unmanned aerial vehicles (UAVs) and integrated around the signal lines of NTN ground stations
- Direct connection without lossy cables
- Can measure different frequency bands without the need for an external downconverter

This contributes to more efficient installation and maintenance work in the field.



<u>Visualize the following evaluation items</u>

- Channel Power
- Spectrum
- Adjacent Channel Leakage Power
- Spurious Emissions
- Occupied Bandwidth

etc.

Monitoring Satellite Signals and Unwanted Radio Waves at NTN Ground Stations

Technical Issues

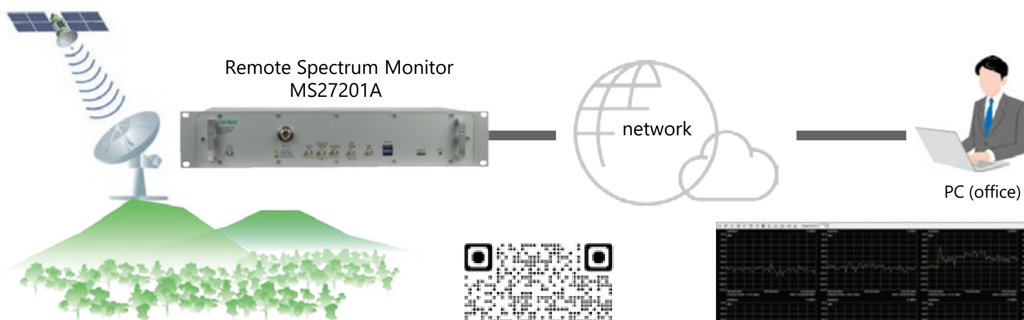
The frequencies of radio waves arriving at ground stations from satellites coexist with those used by terrestrial networks and other applications.
The downlink radio wave strength is very low due to atmospheric absorption and attenuation by rain, making it susceptible to interference from other radio waves.
To ensure stable communications, it is necessary to continuously monitor the radio signals being exchanged between the satellite and the ground station. In addition, it is necessary to continuously monitor radio waves in the adjacent frequency bands and take immediate action, such as filtering out unnecessary radio waves, if any abnormalities such as interference are detected.

Problem-Solving Solutions

- Continuous monitoring of satellite signals
- Spectrum monitoring to detect jamming and interference
- Remote centralized control of spectrum monitors installed at multiple ground stations

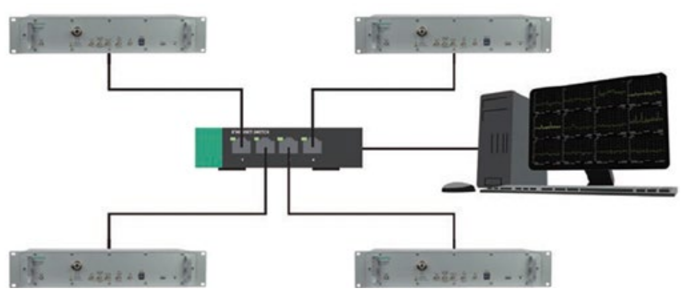
Testing Solutions

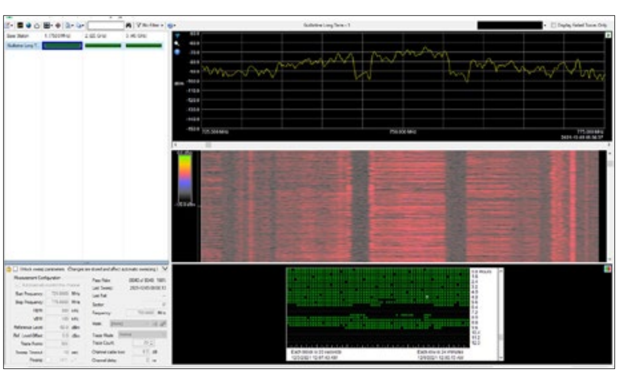
Anritsu remote spectrum monitors are ideal for the constant monitoring of satellite signals and jamming/interference radio waves.



Product details here

- A spectrum analyzer that supports remote control, eliminating unnecessary costs such as large touch panels.
- Interference monitoring with long-term recording and alarms/ alerts: Dedicated software (Vision™)
- When power is restored after a power outage, the system automatically recovers and resumes monitoring in the same state as before the power outage.
- For ground stations with multiple antennas, an MS27201A can be placed on each antenna, allowing monitoring from a PC installed in a remote location.





Long-term monitoring data (Vision™)

- **Functions designed for long-term monitoring:** Signals are monitored over extended duration, with the measurement results being periodically uploaded to a database. History can be recorded over months/years.
- **Capture of short-term/intermittent signals:** Set and extract limit lines for automatic alarms.
- **Searching of stored data:** Stored data can be searched to determine whether a signal of interest exists, e.g. to prove the presence of illegal/unauthorized signals.

Verification of NTN Communication Latency

Technical Issues

NTN's communications can involve ultra-long distances of up to 36,000 km, both between satellites and between satellites and the ground stations. For this reason, while the communication latency in terrestrial networks is small (less than a few hundred μs), in the case of GSO and GEO, for example, the one-way latency can be as high as approximately 120 ms while the round-trip value can be 240 ms. The latency depends on the transmission distance so that that for LEO is smaller than GEO at 6 to 30 ms round trip, and less than 1 ms for HAPS, which involves an even lower altitude. Therefore, to compensate for this delay, 3GPP requires that the transmitter of the wireless signal adjust the transmission timing, etc.

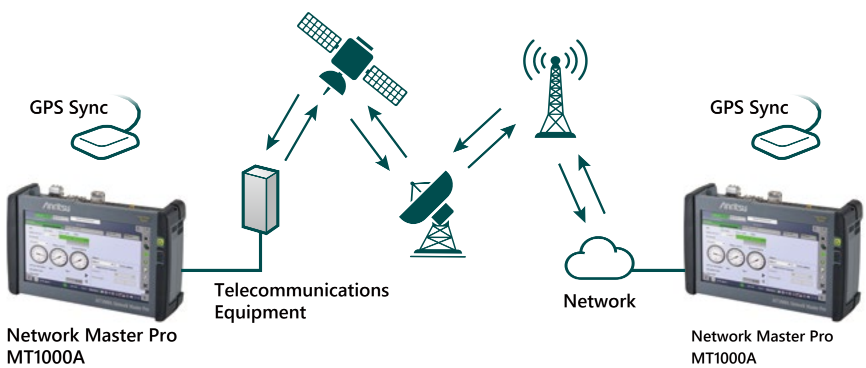
However, with the further development of NTN, satellites at different altitudes and HAPS will be used as relay stations to further expand the area where communications services are provided, such that the latency will vary depending on the communication route. As a result, it is expected that the delay correction performed by the NTN will become more complex and there will be an increasing need to verify the validity of the degree of correction.

Problem-Solving Solutions

- NTN delay time verification
- End-to-end communication quality evaluation to prevent network problems and accidents

Testing Solutions

Anritsu's field test instrument, the Network Master Pro MT1000A can verify the practical latency and communication throughput of the NTN.



The MT1000A uses a dedicated GPS receiver to obtain time information and measures the one-way delay between multiple distant locations (the image shows two locations). By continuously evaluating the time and the delay at any instant, network load fluctuations can also be captured.

Example graph of delay time fluctuation

Communication quality evaluation items

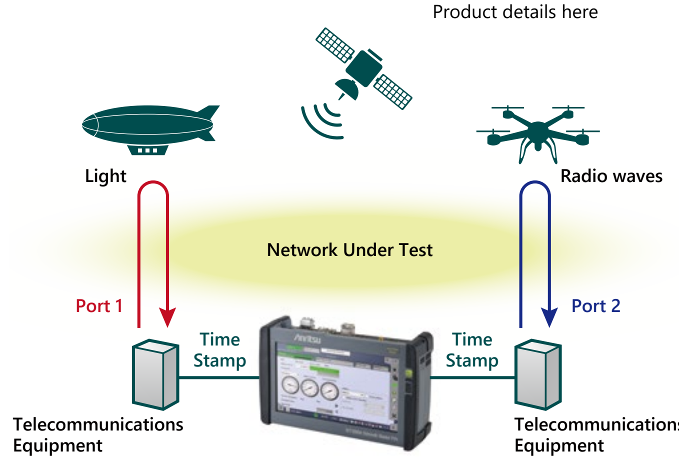
- Delay Time
- Throughput
- Frame Loss
- Packet Jitter

etc.

Product details here

Latency Comparison for different communication paths

If the network has a function for returning packets via loopback, it is possible to send test packets from the measuring instrument and compare the delays incurred by different communication paths. The figure on the right shows an example of a hybrid radio-optical network, together with a measurement system for evaluating the network performance, such as the throughput, delay, and jitter of both networks.



Ensuring Communication Quality Across NTN and Terrestrial Networks

Technical Issues

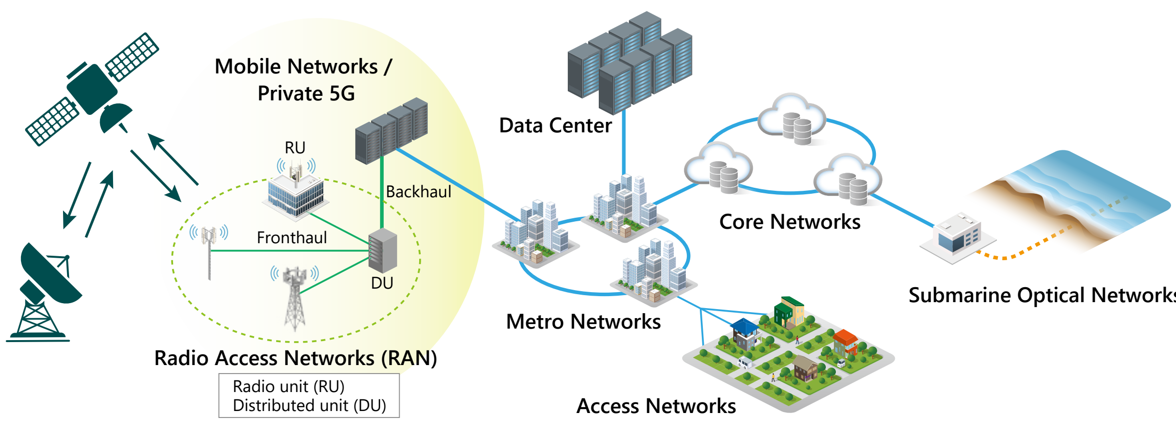
In practical operation, an NTN will be used in conjunction with terrestrial wireless and optical networks. Currently, the boundaries of operator responsibilities regarding the communication quality of each network have essentially been clarified.
However, as networks continue to become more open, the boundaries of responsibility of each network are expected to become less clear. Therefore, in the future, it is expected that there will be a need to check the network status and communication quality at multiple locations on these networks.

Problem-Solving Solutions

• Communication quality tester that supports a range of communication protocols
• A wide range of communication speeds can be evaluated

Testing Solutions

Anritsu's portable field test instrument, the Network Master Pro, can be used for testing a wide variety of communication networks during installation and maintenance.



Product details here

Network Master Pro MT1000A/MT1040A

Product details here

<u>Features</u>

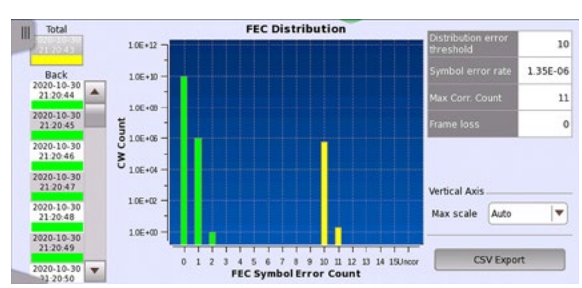
• Supports all types of field testing of transport networks
• Supports 400ZR and Open ZR+ (also supports OpenROADM QSFP-DD)
• Use OTDR modules to pinpoint faults in fiber optic networks
• Test automation using test scenarios

<u>Supports a variety of communication protocols</u>

Ethernet: 10 Mbps to 400 Gbps
OTN: 2.5G/10G/40G/100G
Mobile xhaul: eCPRI/RoE/CPRI/OBSAI

<u>Measurement features</u>

Delay
Throughput
Frame Loss
Packet Jitter
Bit Error Rate
FEC Analysis
etc.



Verification of Automotive Communication Latency

Industry Trends

Currently, terrestrial mobile networks are widely used for wireless communication between automobiles and external networks. However, NTNs are attracting attention because they can provide communications in areas that are not covered by terrestrial networks. NTNs are expected to ensure network redundancy in emergencies because they are less susceptible to physical damage caused by natural disasters. By utilizing an NTN, it will be possible to provide seamless communications services through satellite and stratospheric communications to vehicles in areas that cannot be reached by conventional terrestrial networks. This initiative will also contribute to expanding emergency reporting, surveillance, and entertainment services. In the future, NTNs may be used more widely in communication services for software-defined vehicles (SDVs) and connected cars, as well as in C-V2X and autonomous driving technologies. In this way, NTNs are expected to play a key role in the future of automotive communications.

Technical Issues

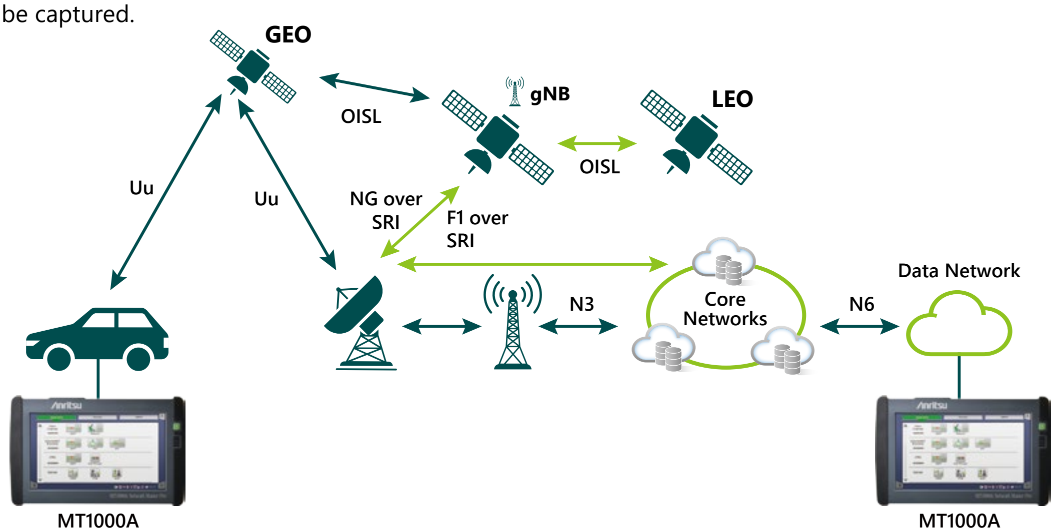
In autonomous driving and connected-car systems, which require real-time performance, communication delays have a direct impact on safety and performance. For example, in situations where an autonomous vehicle needs to recognize its surrounding environment in real-time and make quick decisions, communication delays could prevent it from reacting appropriately, which could lead to accidents. NTNs incur a larger communication latency than terrestrial networks, so it will be necessary to verify the latency in the field.

Problem-Solving Solutions

• Verifying delays
• End-to-end communication quality evaluation to prevent network problems and accidents

Testing Solutions

A dedicated GPS receiver is used to obtain time information, and the one-way delay between multiple distant locations (the following figure shows two locations) is measured. By continuously evaluating the time and the delay at any instant, network load fluctuations can also be captured.



Example graph of delay time fluctuation

Communication quality evaluation items

• Delay Time
• Throughput
• Frame Loss
• Packet Jitter
etc.

Product details here