Maury Microwave & Rohde & Schwarz

SOLUTIONS FOR 5G NTN

Maury Microwave

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Introduction

As part of the 5G revolution, Non-Terrestrial Networks (NTN) have become essential for expanding coverage and enabling global connectivity. When fully realized, the integration of satellite communication systems with 5G will allow for high-speed, low-latency communication even in remote regions, far beyond the reach of traditional terrestrial networks. Satellite channel emulation, also referred to as link emulation, ensures that 5G NTN systems perform reliably in real-world scenarios.

Satellite channel emulation simulates the behavior of a satellite communication channel in a controlled environment, allowing engineers

to evaluate and optimize satellite communication systems without the need for live satellite links. Common factors affecting satellite channel links include signal attenuation, Doppler shift, propagation delays, ionospheric scintillation, and multipath effects. These conditions are precisely emulated to validate the performance and reliability of communication systems.

Why It's Important:

> Cost-Effective Testing: Emulation provides a cost-effective alternative to expensive live satellite testing.

> Early Problem Detection: It helps identify problems and optimize systems before launching a satellite or establishing a live satellite link.

> Development and Optimization: Engineers can use it to develop and optimize satellite communication systems (antennas, modems, and protocols).

> Reduced Risk: Simulating extreme conditions (e.g., atmospheric disturbances) helps improve system reliability and reduce the risk of failure once operational.

> Performance Validation: Emulation ensures the system's functionality and performance under different scenarios, including those that may not occur frequently in the real world but are critical for reliable service.

This document presents comprehensive solutions from Rohde & Schwarz and Maury Microwave, focusing on 5G NTN system testing and validation.

The Rohde & Schwarz SMW200A Vector Signal Generator[1] can be used for satellite channel emulation due to its advanced capabilities in generating complex RF signals. It can emulate satellite communication environments and test satellite receivers under a variety of conditions, with built in fading, Doppler and AWGN capabilities.

However, there are scenarios where a signal generator cannot be used, since the customer DUT (i.e. modem, gNodeB…) generates the signal. Additionally, there are scenarios where true impairments are desired based on a particular orbit ephemeris data. In these cases, a standalone emulator, such as the Maury Microwave (dBm) ACE 9600 Advanced Channel Emulator[2], is used to create realistic satellite communication link effects.

In several scenarios, a signal analyzer, such as a Rohde & Schwarz FSW-series Signal and Spectrum Analyzer[3] can be used with the Maury Microwave (dBm) ACE 9600 Advanced Channel Emulator to test and verify the satellite communication signal quality, measure distortion and interference, frequency response, and signal strength.

Finally, a Rohde & Schwarz CMX500 Radio Communication Tester[4] can be used in conjunction with the Advanced Channel Emulator for scenarios where 5G New Radio interface over satellite networks needs to be simulated.

[1] https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_brochures_and_datasheets/specifications/3606_8037_22/SMW200A_specs_en_3606-8037-22_v2600.pdf

[2] https://dbmcorp.com/wp-content/uploads/2024/08/ACE-brochure.pdf

[3] https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_brochures_and_datasheets/specifications/5215_6749_22/FSW_specs_en_5215-6749-22_v1500.pdf

This document presents comprehensive solutions from Rohde & Schwarz and Maury Microwave, focusing on 5G NTN system testing and validation, covering the following scenarios:

- Scenario 1: Receiver Testing at the Physical Layer
- Scenario 2: MIL 5G NTN End-to-End Testing
- Scenario 3: 5G NTN Transparent Payload Testing

The ACE9600 fully supports the NR-NTN uplink and down link bands n254, n255 & n256 with internal L/S band RF converters. Frequencies at Ka-band (FR2) as defined in Release 18 will require the use of extended-range external RF converters from Maury as a companion product with the ACE9600.

[4] https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/pdm/cl_brochures_and_datasheets/product_brochure/5216_4127_12/CMX500_bro_en_5216-4127-12_v0500.pdf

Scenario 1: Receiver Testing at the Physical Layer

Receiver testing at the physical layer is essential for evaluating the performance of satellite communication (SATCOM) systems, particularly the receiver's ability to process incoming satellite signals under real-world conditions. Physical layer testing focuses on measuring the receiver's ability to handle modulated signals, deal with interference, and perform under various conditions of noise, distortion, and fading.

Key performance metrics include:

> Signal reception quality
> Interference handling
> Error performance
> Noise resilience
> Doppler shift pre and/or post compensation
> Sensitivity and dynamic range
> Frequency stability and accuracy

To perform the test procedures related to Receiver Testing, the following equipment is required:

> Vector signal generator used to create complex SATCOM signals
> Channel emulator to create impairments (e.g., delay, Doppler shift, fading, and noise).
> Receiver (DUT)

The R&S SMW200A can be used as both the signal generator and the channel emulator, in situations where the SMW's ability to create impairments is sufficient for the test, typically the first stage of SATCOM Receiver testing, as shown below.

When impairments based on orbit ephemeris data are preferred and/or to have consistent impairments end-to-end test, a Maury Microwave (dBm) ACE9600 can be inserted between the SMW200A and the receiver, as shown below.

In certain case customer specific or proprietary/privileged signals may be required to test the receiver at the physical layer. In this scenario the signal generator can easily be replaced by a user supplied Modem or similar as shown below.

Example DUTs include:

> UE transceivers (subset of UE in non-signaling mode)
> Gateway/relay communications transceivers
> Satellite payload communications transceivers
> Software defined radios (SDR's)

Scenario 2: MIL 5G NTN End-to-End Testing

MIL 5G NTN end-to-end testing involves testing how 5G NTN devices communicate through satellite links, ensuring seamless integration with terrestrial and non-terrestrial (satellite) 5G networks. This process ensures that all components—satellites, ground stations, and terrestrial infrastructure—operate cohesively and meet performance, reliability, and interoperability standards under real-world conditions.

Key performance metrics include:

> Seamless integration and handovers

> Performance validation

> 5G NTN Interoperability

> Mobility support

> QoS and security testing

The following equipment is required:

> User equipment (DUT)

> Channel emulator to create impairments (e.g., delay, Doppler shift, fading, and noise).

> User equipment (DUT)

The simplest method to perform end-to-end SATCOM link testing is to insert a Maury Microwave (dBm) ACE9600 between the communication ends (DUTs) to create link impairments, as shown below.

If problems are identified, one end (DUT) can be replaced by the R&S FSW spectrum analyzer to troubleshoot the signals, as shown below.

In addition to generating ephemeris-based impairments the ACE9600 can also generate hardware-in-the-loop (e.g. payload) impairments such as amplifier compression/distortion, passband shaping (IMUX/OMUX) and programmable phase noise to verify End-to-End testing not only in the presence of link impairments, but also with sub-optimal hardware-in-the-loop degradation.

It is important to note that upconverters/downconverters can be utilized with the channel emulator to expand its operating range, when signal frequencies are outside of the operating frequency of the instrument.

Example DUTs include:

> User equipment (UE's)

> SATCOM modems/ground stations

> UHF/VHF communications devices, software defined radios etc

> Communication payloads

> UAV's

Scenario 3: 5G NTN Transparent Payload Testing

5G NTN transparent payload testing involves validating the end-to-end performance of the 5G NTN communication chain, from the UE through the satellite payload back to the core network.

Key metrics include:

> 5G NTN-specific throughput testing

> Signal robustness

> Quality of Service (QoS) adherence under satellite conditions

> QoS adherence

The following equipment is required:

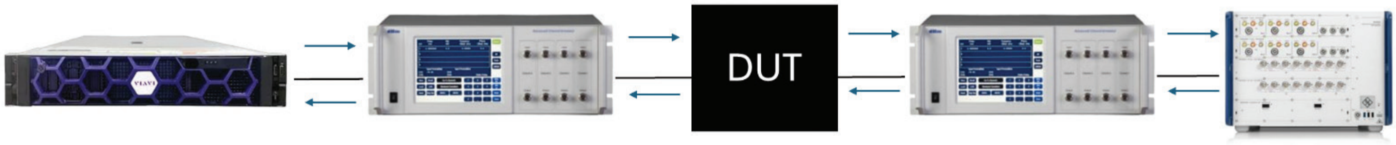
> User Equipment (UE) emulator to simulate a user device, providing the traffic (voice, video, data) that would be transmitted through the satellite link.

> Channel emulator to create impairments (e.g., delay, Doppler shift, fading, and noise).

> Transparent payload (DUT)

> Satellite network emulator to simulate the satellite-based network, including ground stations, gateways, and potentially the core network infrastructure, providing end-to-end network emulation.

A UE emulator, such a Viavi TM500, can be used with a Maury Microwave (dBm) ACE9600 Channel Emulator and R&S CMX500 Radio Communication Tester to carry out a complete payload test, as shown below.



Example DUTs include:

> Transceivers

> Repeaters

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