

UNLOCKING THE POWER OF SATELLITE CHANNEL EMULATION

INTRODUCTION TO THE R&S SPACE NEXUS
WITH R&S®SMW200A AND R&S®FSW

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ROHDE & SCHWARZ

Make ideas real



AGENDA

- Fundamentals of Satellite Propagation
- Propagation and Calculation of Satellite to Ground Channels
- Testing Solutions for Emulating the RF Channel from Satellite to User Equipment and vice versa
- DEMO: Demonstration of Space Nexus Functionality and Its Application in a Test Environment

CHANNEL EMULATION INTRODUCTION

CHANNEL EMULATION AND WHY YOU NEED IT

- ▶ **What:** Channel emulation simulates the effects of the channel between a satellite and a DUT, on the communication signal used
- ▶ **Why:** Actual satellite testing is costly, time-consuming, and unpredictable due to environmental factors
- ▶ **Benefits:** Enables controlled and repeatable testing in a laboratory environment, reducing risk and improving system performance



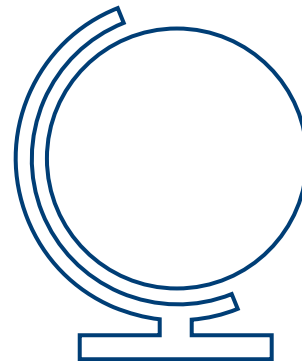
GEO



MEO

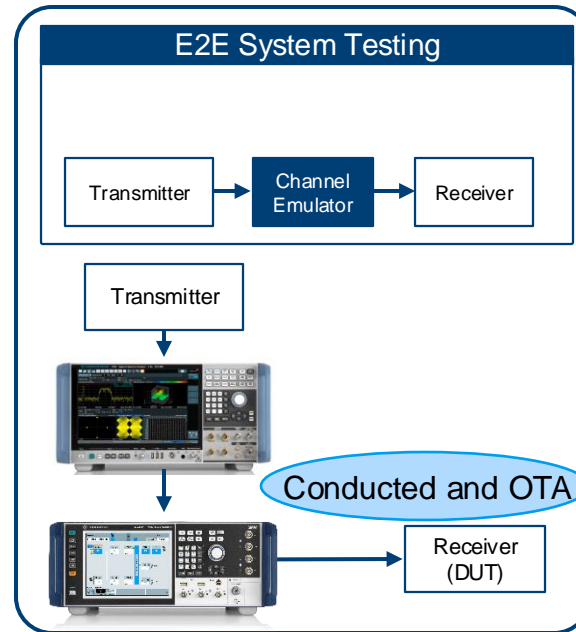
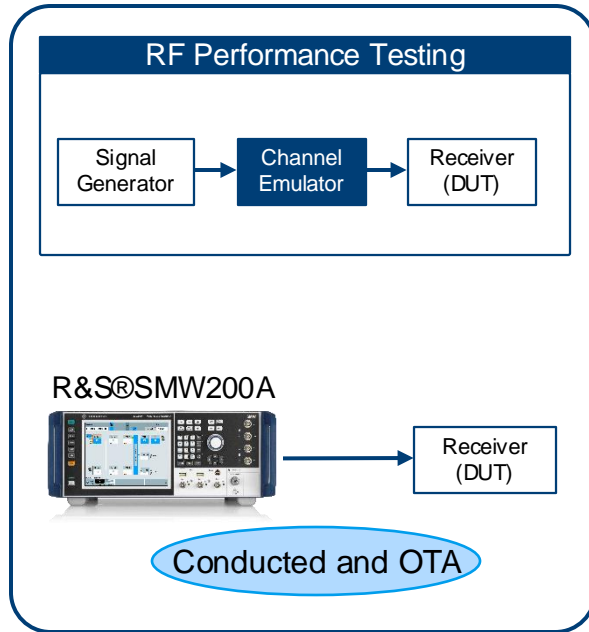


LEO



APPLICATIONS FOR THE CHANNEL EMULATION SOLUTION

R&S®SMW200A is a versatile channel emulator



R&S SMW-K820: CUSTOM DYNAMIC FADING

R&S SMW-K820 BACKGROUND CLASSIFICATION OF FADING SCENARIOS



Set of fading parameters (delay, doppler shift, path loss..)

Time-variant parameters

Customized dynamic scenarios

State	Profile	Speed	D (m)	D (s)	Consider DL NF	Start Offset	Virtual DL SF
OFF	Pure Doppler	None	Matrix	✓			
OFF	Pure Doppler	None	Matrix	✓			
OFF	Pure Doppler	None	Matrix	✓			
OFF	Pure Doppler	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			

Time-invariant fading profiles

State	Profile	Speed	D (m)	D (s)	Consider DL NF	Start Offset	Virtual DL SF
OFF	Pure Doppler	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			
OFF	Rayleigh	None	Matrix	✓			

Pre-defined dynamic scenarios

State: 1

Profile: Pure Doppler

Speed: 8.000 m/s

D (m): 2.0 m

D (s): 200 m

Consider DL NF:

Start Offset: 0.0 ps

Virtual DL SF: 1.000 000 000 GHz



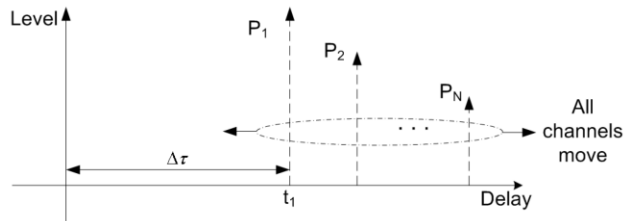
R&S SMW-K820 BACKGROUND

PRE-DEFINED DYNAMIC SCENARIOS

SMW-K71

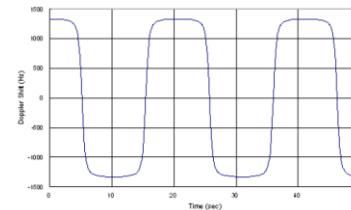
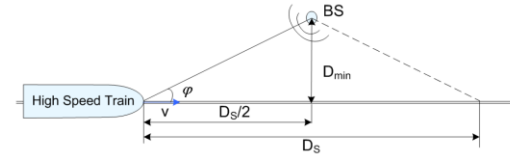
3GPP Moving Propagation

- In conformity with basestation conformance specs
- For uplink timing adjustment
- Scenario: moving UE(s) or NTN



3GPP High Speed Train

- In conformity with basestation conformance specs
- Scenario: UE inside high speed train



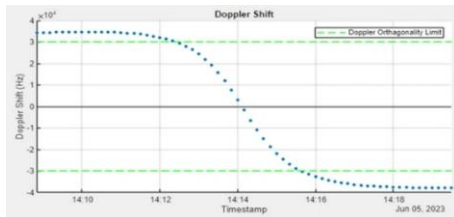
Exemplary doppler variation for open space scenario

R&S SMW-K820 BACKGROUND CUSTOMIZED DYNAMIC SCENARIOS



5G NTN E2E System Testing

- Emulation of link between UE and satellite
- Proprietary models for satellite link



Other possible scenarios

- Ship to ship



- Links to missiles, planes..



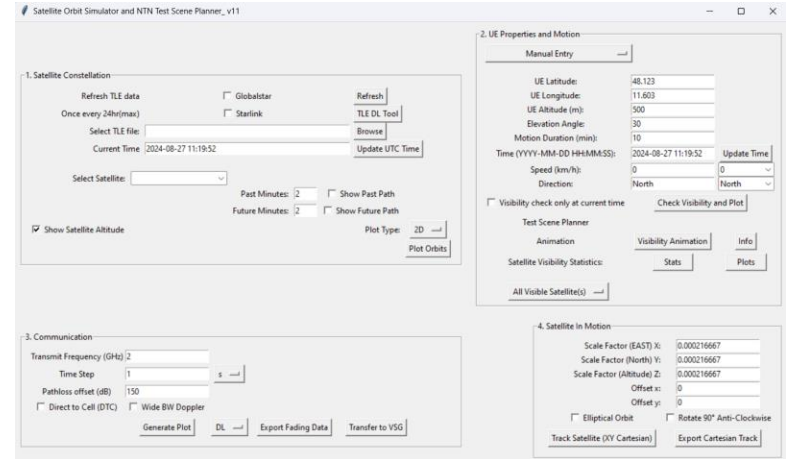
Complex

In the past, complex to generate appropriated files.

R&S SPACE NEXUS

R&S SPACE NEXUS OVERVIEW

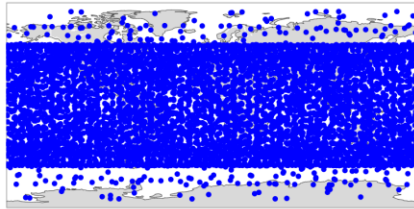
- ▶ An external software tool to generate NTN test scenarios and to generate fading files for the R&S®SMW200A based on a satellite trajectory.
- ▶ Only unofficial product with limited support.



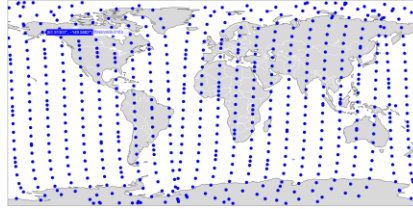
IMPORT SATELLITE CONSTELLATION

2D & 3D VISUALIZATION

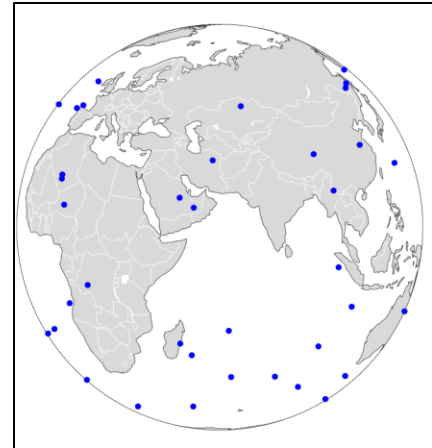
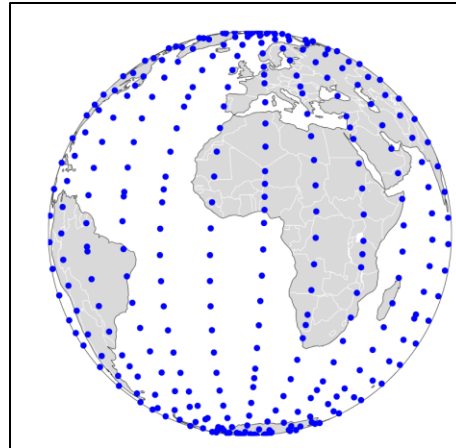
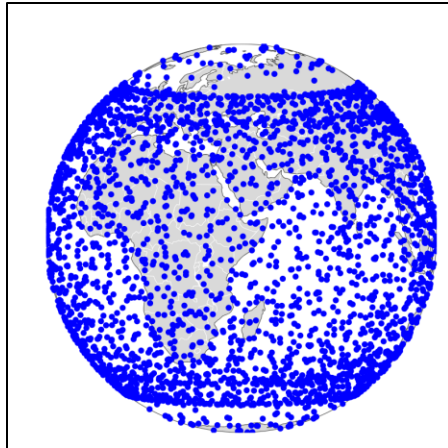
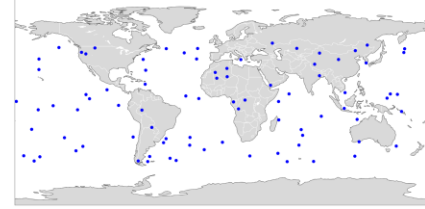
Starlink



Oneweb



Globalstar



CHECKING VISIBILITY

- ▶ Check for all satellites visible for the given location and movement

2. UE Properties and Motion

Manual Entry

UE Latitude: 28.558613

UE Longitude: -81.405609

UE Altitude (m): 500

Elevation Angle: 30

Motion Duration (min): 10

Time (YYYY-MM-DD HH:MM:SS): 2024-09-13 10:12:42

Speed (km/h): 0

Direction: North

Visibility check only at current time

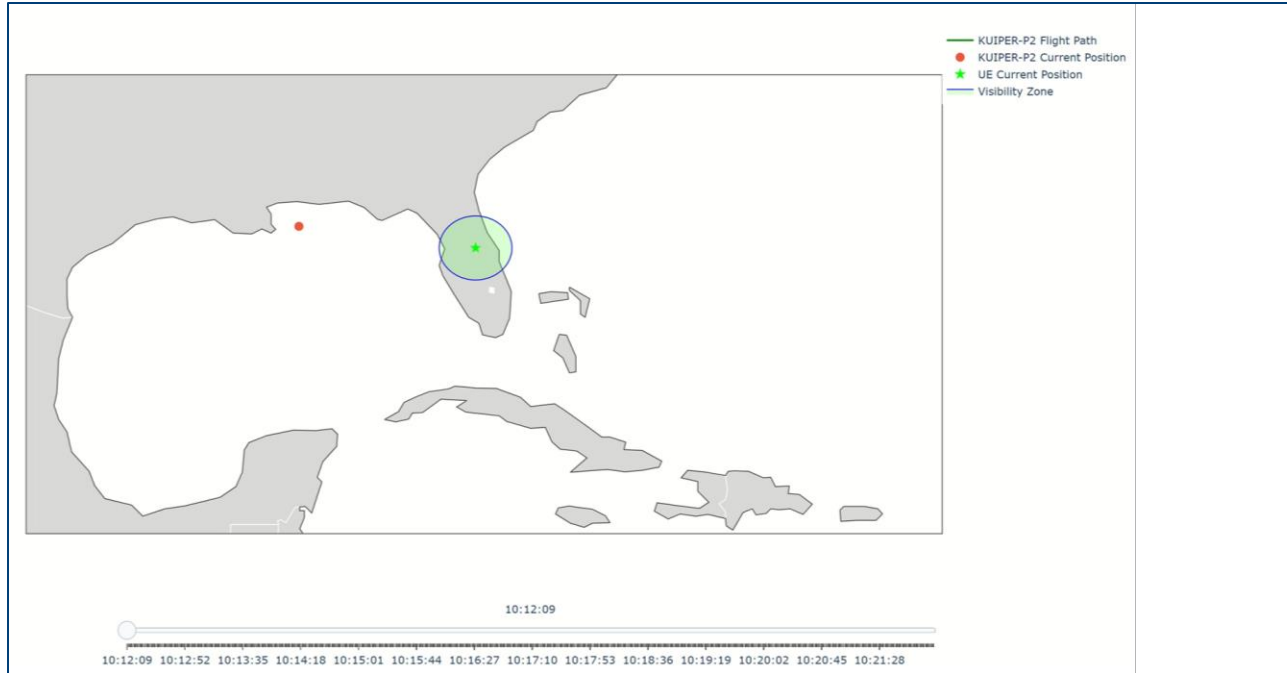
Test Scene Planner

Animation

Satellite Visibility Statistics:

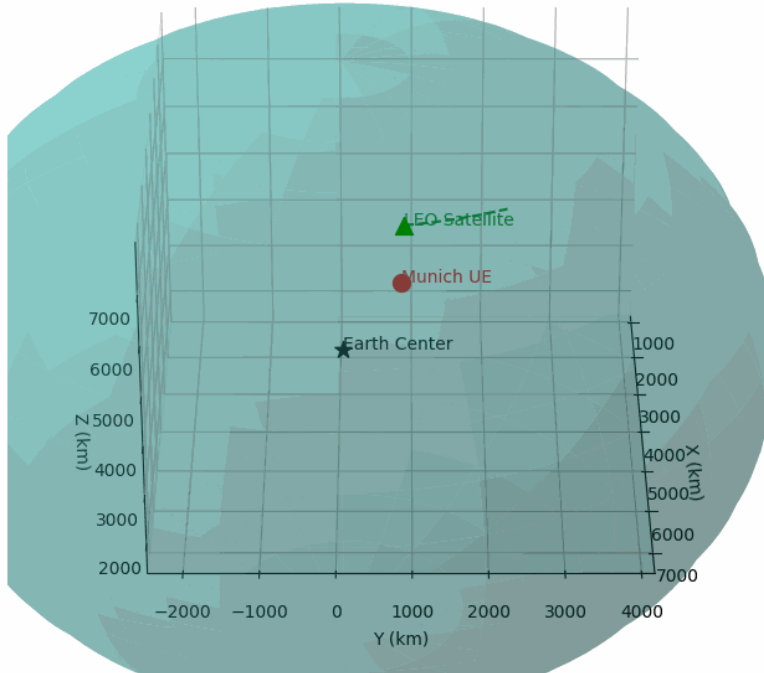


CHECKING VISIBILITY



RF CHANNEL PARAMETER CALCULATION

Animated ECF conversion: Zoomed in and Rotating with Moving Satellite



3. Communication

Transmit Frequency (GHz)

Time Step

Pathloss offset (dB)

(CL) Clutter Loss (dB)

(SF) Shadow Fading (dB)

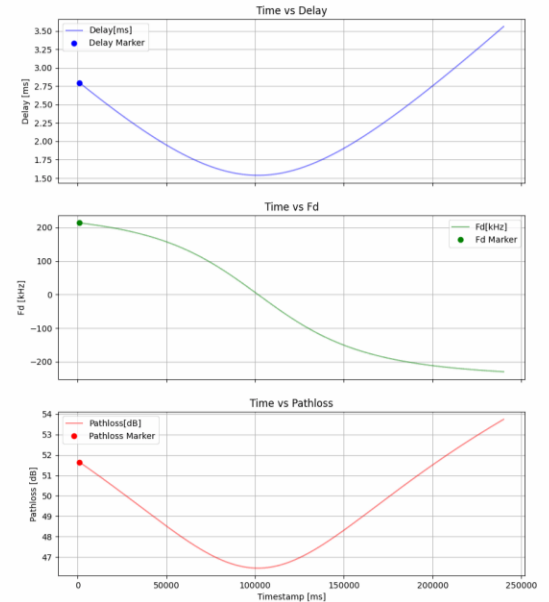
Use Default CL & SF

Direct to Cell (DTC) Wide BW Doppler

Apply LB configuration

Path Delay Offset(ms)

Use Shortest Path to Gateway for Latency



FADING FILES

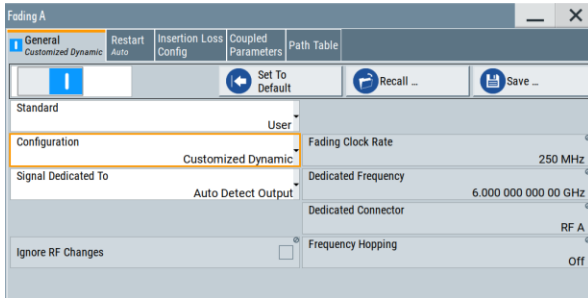
	Interval[us]	Delay[ms]	Fd[kHz]	Pathloss[dB]
1	50	7.534877	47.055121	15.554548
2	50	7.534875	47.055121	15.554546
3	50	7.534874	47.055121	15.554545
4	50	7.534873	47.055121	15.554544
5	50	7.534872	47.055121	15.554542
6	50	7.534871	47.055120	15.554541
7	50	7.534869	47.055120	15.554540
8	50	7.534868	47.055120	15.554538
9	50	7.534867	47.055120	15.554537
10	50	7.534867	47.055120	15.554537

Key parameters

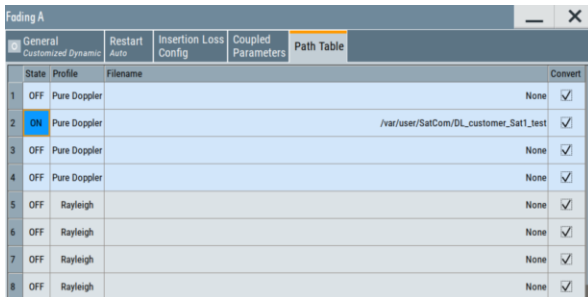
- Update interval
- Delay
- Doppler
- Pathloss



R&S SMW-K820 GUI SETTINGS



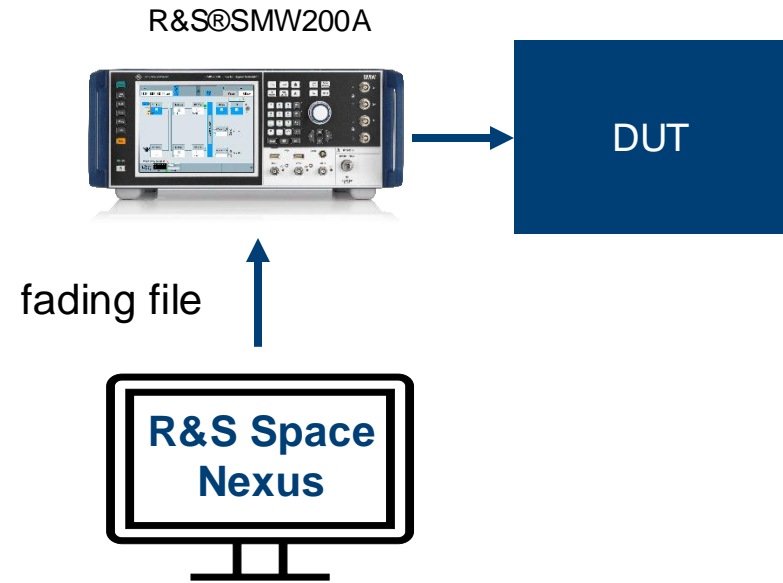
- ▶ Fading Settings: Choose „Customized Dynamic“ as Configuration



- ▶ Path Table: Load the dynamic fading list files for each path (max. number of paths: 12)
- ▶ Path 1...4: Pure Doppler / Rayleigh / Static
- ▶ Path 5..12: Rayleigh

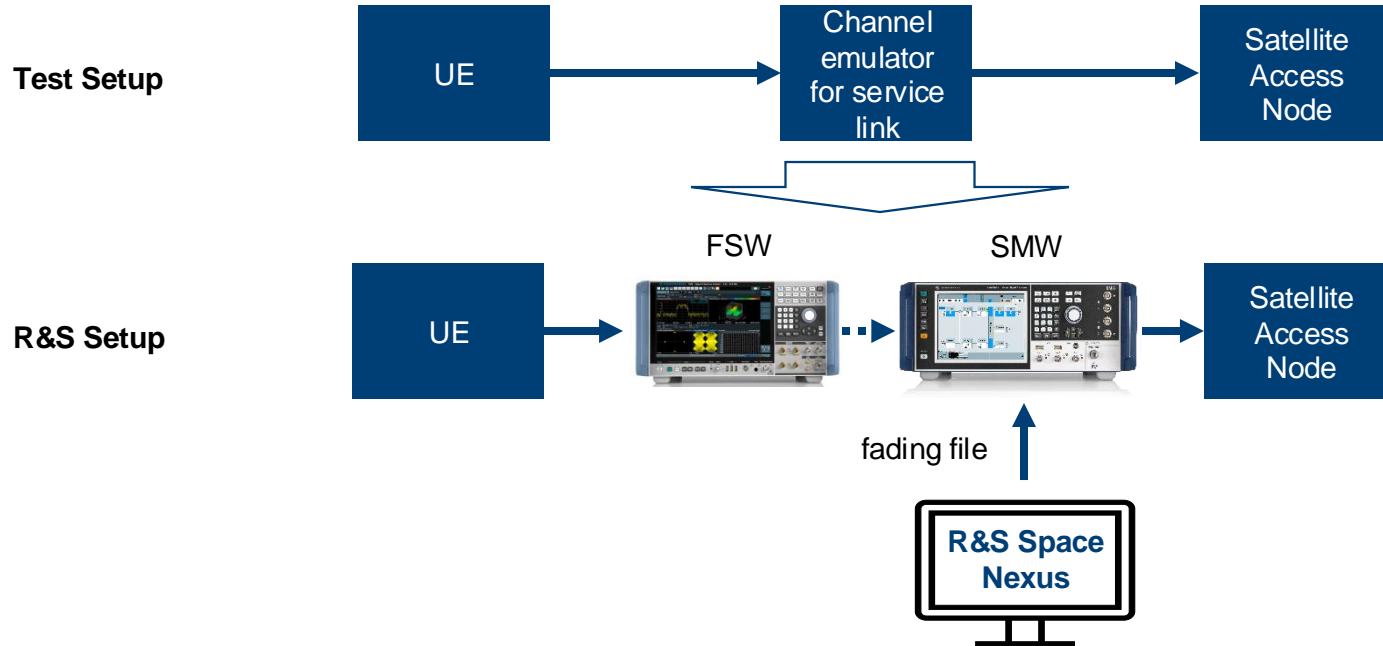
KEY FACTS

- ▶ Up to 67 GHz
- ▶ Up to 200 MHz fading bandwidth
- ▶ Maximum doppler of 1.953 MHz
- ▶ Maximum path delay of 1s
- ▶ Minimum resolution of 50 μ s



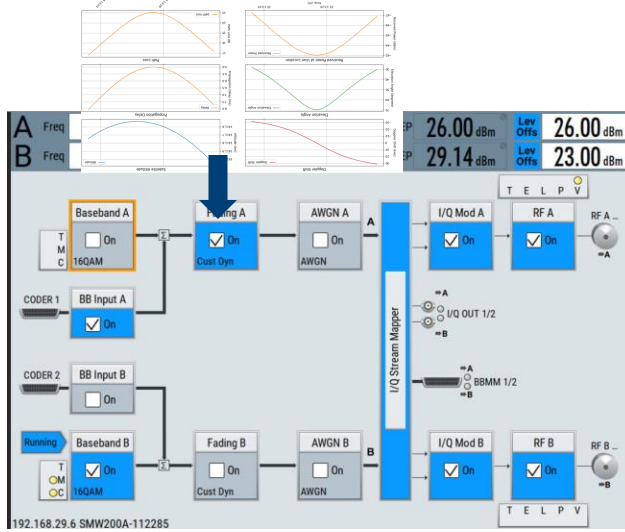
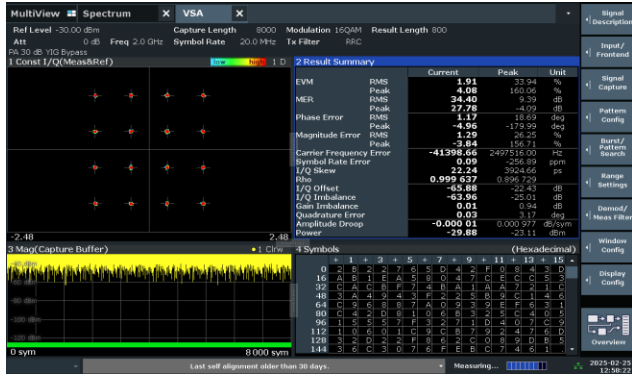
END-2-END-CHANNEL EMULATION

END-2-END-TESTING R&S SETUP FOR CHANNEL EMULATION



DEMO

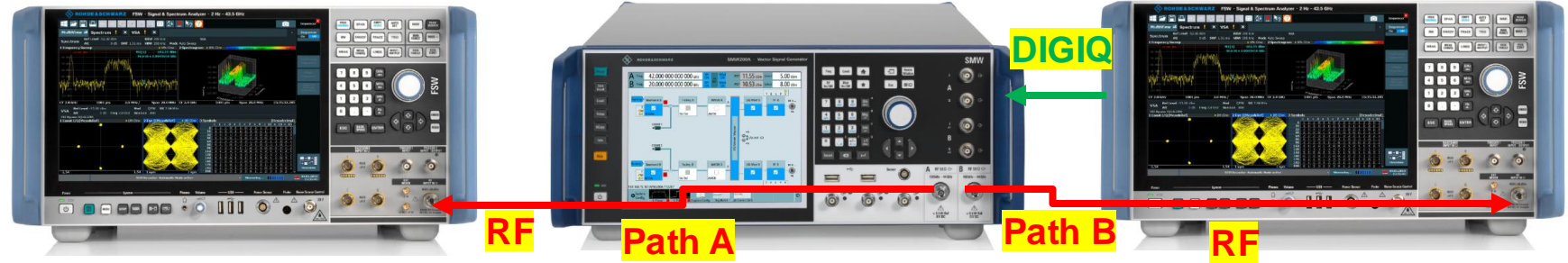
The background of the slide features a series of diagonal stripes. The stripes alternate between a very dark blue and a medium blue color, creating a sense of depth and movement. The stripes are parallel and run from the top-left towards the bottom-right.



FSW 2

SMW

FSW 1



PATH B

- ▶ 16 QAM
- ▶ RRC 0.2
- ▶ Fc: 2GHz
- ▶ Symbol Rate: 20.00 Msym/s



Custom Digital Modulation B

General | Trigger In Auto | Marker | Clock Internal | Data Source PRBS 9 | Modulation 16QAM | Filter RRC

Set according to Standard User

Symbol Rate 20.000 000 000 Msym/s

Coding Off

Power Ramp Control ... Off / Cosine / 1.00 sym

A Freq 2.000 000 000 000 GHz RF On Int Ref Mod On PEP 0.00 dBm Level 0.00 dBm

B Freq 2.000 000 000 000 GHz RF On Mod On PEP -14.01 dBm Level -20.00 dBm

Custom Digital Modulation B

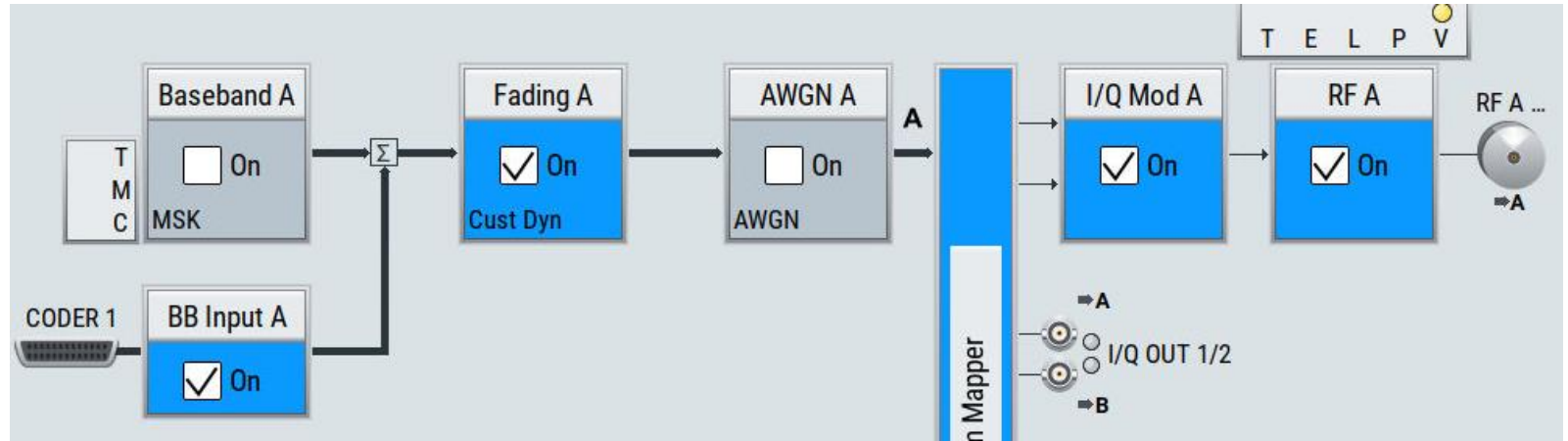
General | Trigger In Auto | Marker | Clock Internal | Data Source PRBS 9 | Modulation 16QAM | Filter RRC

Modulation Type 16QAM

State Modulation CW Switching

PATH A

- ▶ BB Input A -> Custom Dynamic Fading (load fading file)



FADING PROFILE

1. Satellite Constellation

Refresh TLE data Globalstar Starlink Refresh

Once every 24hr(max) TLE DL Tool

Select TLE file: C:/Users/Naseef/New PC/DATA/NTN/TLE/TLE_URL/globe Browse

Current Time: 2025-02-25 13:37:59 Update UTC Time

Total satellites: 85

Select Satellite: All

Past Minutes: 2 Show Past Path

Future Minutes: 2 Show Future Path

Show Satellite Altitude Plot Type: 2D Plot Orbits

2. UE Properties and Motion

Manual Entry

UE Latitude: 48.123

UE Longitude: 11.603

UE Altitude (m): 500

Elevation Angle: 45

Motion Duration (min): 10

Time (YYYY-MM-DD HH:MM:SS): 2025-02-25 13:16:00 Update Time

Speed (km/h): 0

Direction: North

Visibility check only at current time Check Visibility and Plot

Test Scene Planner

Animation Visibility Animation Info

Satellite Visibility Statistics: Stats Plots

GLOBALSTAR M068

3. Communication

Transmit Frequency (GHz): 2

Time Step: 1

Pathloss offset (dB): 180

(CL) Clutter Loss (dB): 25.0

(SF) Shadow Fading (dB): 0.9 Load from Tool

Use Default CL & SF CL & SF Configuration Tool

Direct to Cell (DTC) Wide BW Doppler

Link Budget (LB) Configurator Apply LB configuration

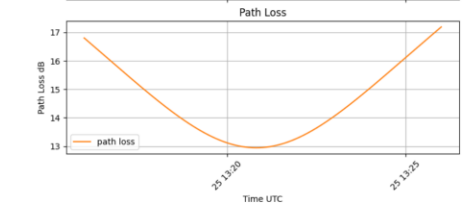
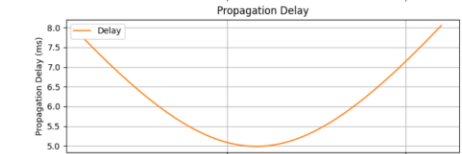
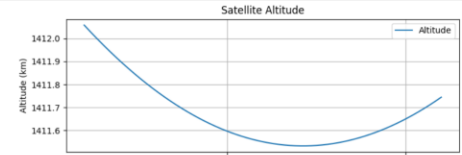
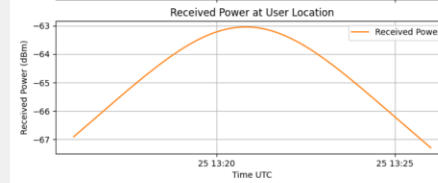
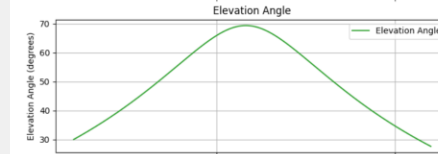
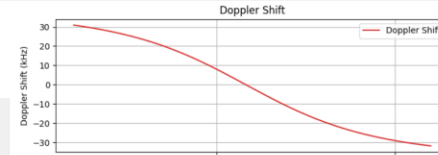
Path Delay Offset(ms): 0

Multihop ISL Path Modeling Use Shortest Path to Gateway for Latency

Generate Plot DL Export

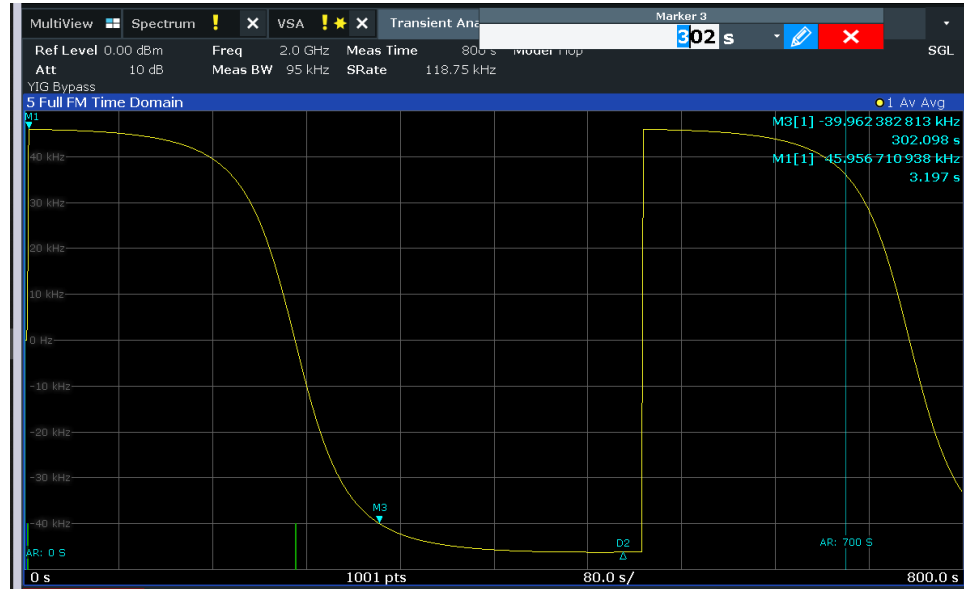
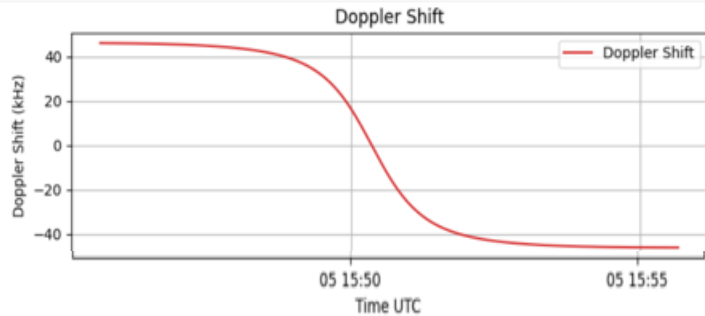
4. Satellite in Motion

Cobot Arm.csv Export

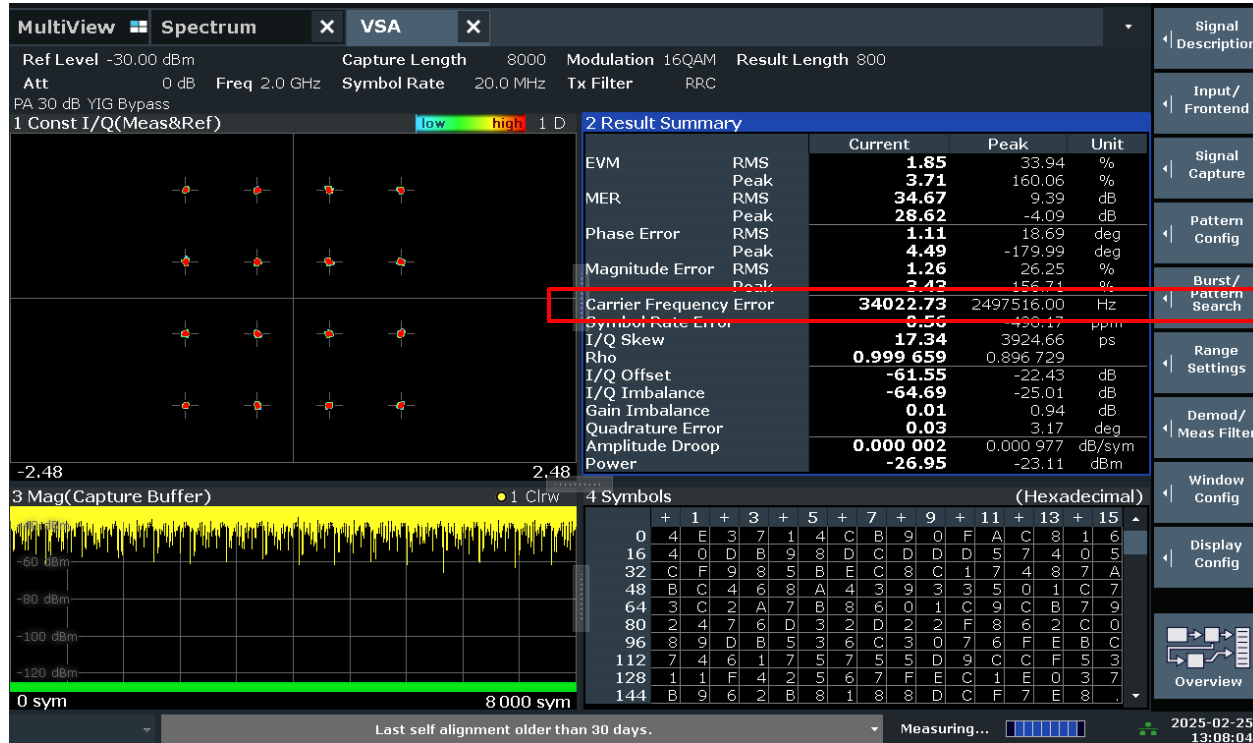


CALCULATED DOPPLER SHIFT APPLIED TO RF SIGNAL

Sine Wave 100Hz
 $F_c = 2\text{GHz}$
Measure BW = 95KHz
SRate = 118.75KHz
Trace = Average

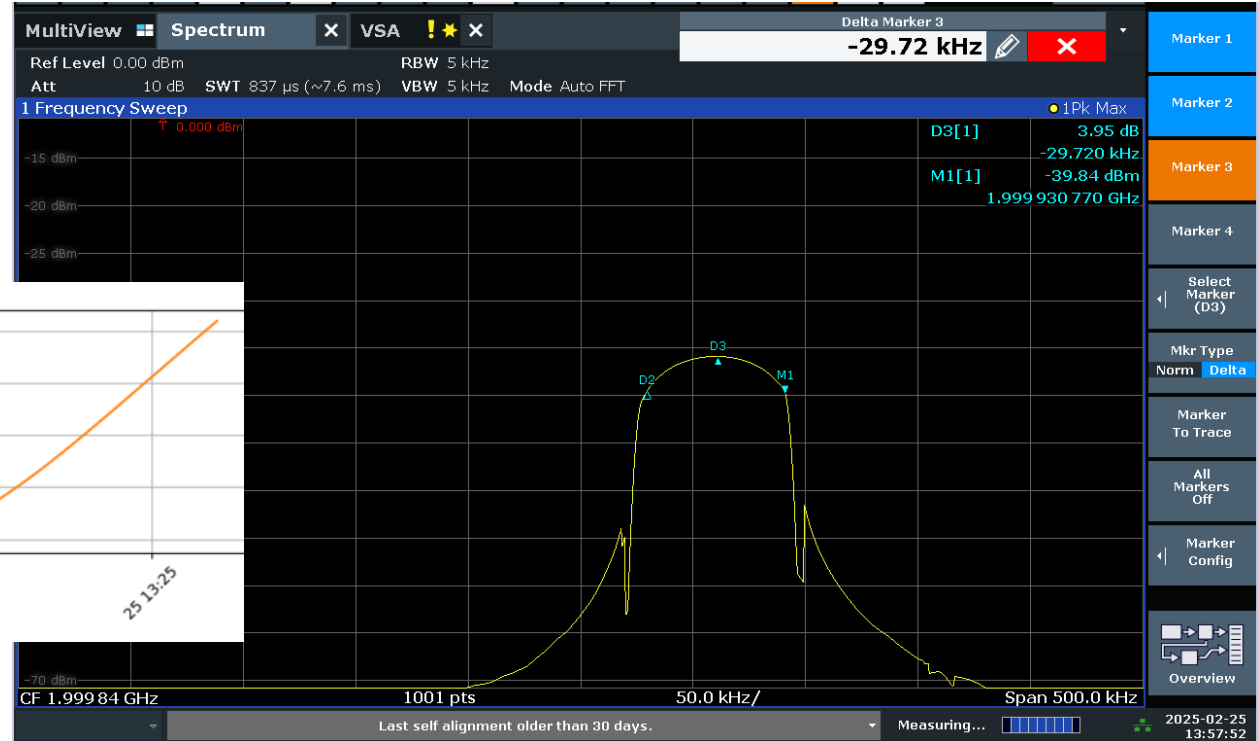
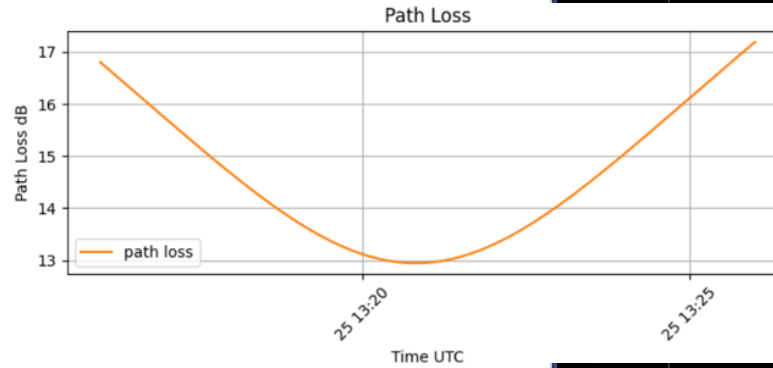


FSW 2 (MEASURING 16QAM AND FADING DATA)



PATH LOSS

- ▶ Test signal
 - 100Hz Sine wave
- ▶ Fading profile added



THANK YOU FOR YOUR ATTENTION