Trends in Equipment Testing in LEO Satellite Operations Webinar

SATELLITE LINK BUDGET ANALYSIS AND OPTIMIZATION

&

SATCOM SPECTRUM MONITORING

Benjamin Jungbauer
SATCOM Solution Manager
11/30/2022

ROHDE&SCHWARZ
Make ideas real

FAIL FAST AND LEARN FAST

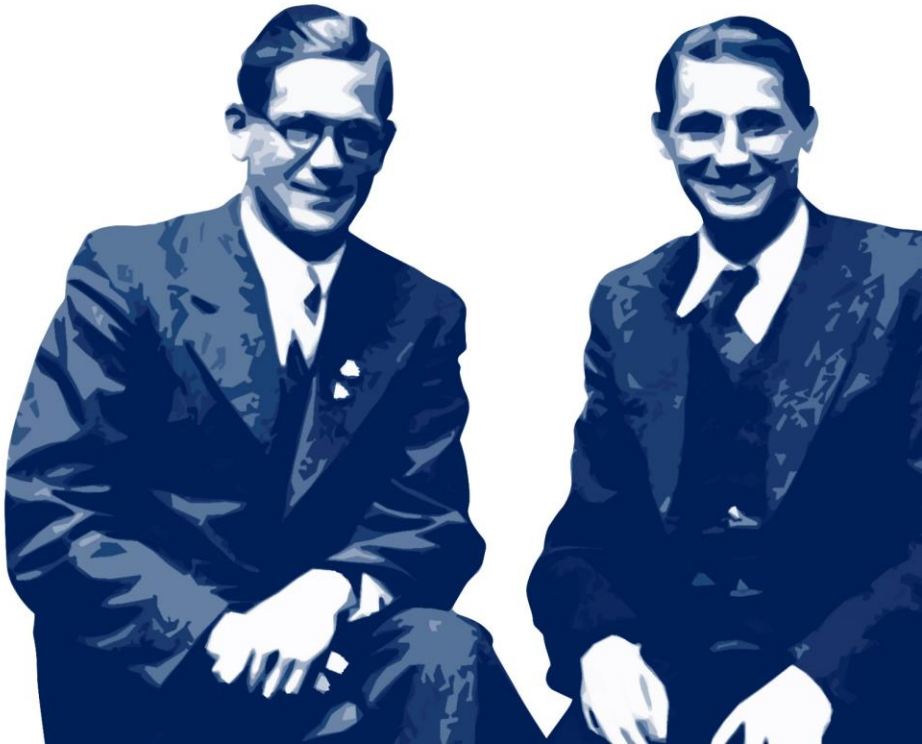
- Rule of ten: cost per error increases by the factor of ten over the value chain
- Simulation helps to verify and validate the intend function of a system
- Rohde & Schwarz supports to simulate SATCOM links in advance and to monitor and analyze the later operation

AGENDA

- Rohde & Schwarz at a Glance
- Satellite Link Planner
- Communication System Monitoring
- Satellite Receiver MSR4

FROM A TWO-MAN LAB TO A PRIVATELY OWNED GLOBAL COMPANY

- Founded in 1933 by university friends Dr. Lothar Rohde and Dr. Hermann Schwarz as "Physikalisch-technisches Entwicklungslabor" ("Physical and Engineering Development Lab")
- Still fully owned by the founding families
- Independent of financial and capital markets
- Tradition of long-term, sustainable and trust based customer relationships
- Since its founding, an enabler and innovator of a safer and connected world



ONE COMPANY, THREE DIVISIONS, DIVERSE MARKETS: WE ARE A RELIABLE TECHNOLOGY PARTNER

TEST & MEASUREMENT

Wireless I Industry, Components & Research I Aerospace & Defense Testing I Automotive

TECHNOLOGY SYSTEMS

Secure Communications I Critical Infrastructure & Networks I Government I IP Network Analytics I Broadcast, Amplifiers & Media

NETWORKS & CYBERSECURITY

Network & Security Solutions I Certified & High-Grade Crypto Solutions



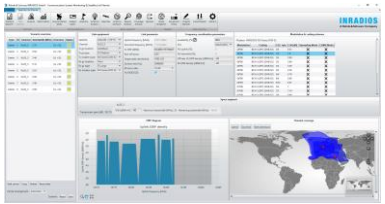



CLOSE TO THE MARKET.
CLOSE TO CUSTOMERS.

- Locations in around 70 countries
- More than 60 subsidiaries
- Worldwide development centers,
  sales and service offices
- 13,000 employees worldwide

ROHDE & SCHWARZ
INRADIOS GMBH

- **Founded in 2010** as a spin-off of TU Dresden
- **Acquired** by Rohde & Schwarz in **2017**
- Currently around **20 experts** focusing on **SATCOM**
- **Strong R&D** background

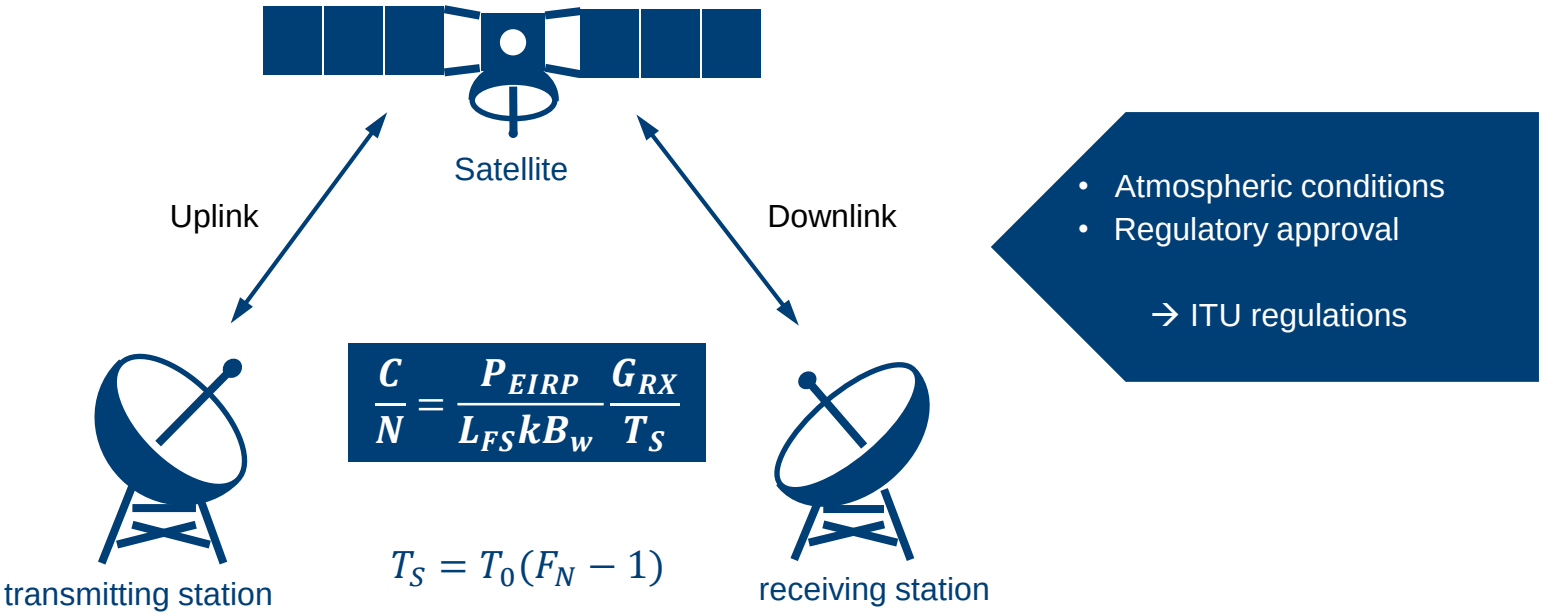


INRADIOS
A Rohde&Schwarz Company

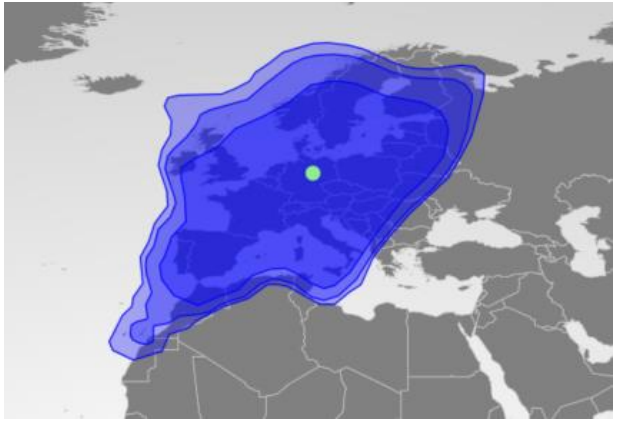
SATELLITE LINK PLANNER (R&S®GSASLP)

THE LINK ENGINEERING TASK

Designing the physical parameters of a link, to ensure a specified data rate under typical use case conditions



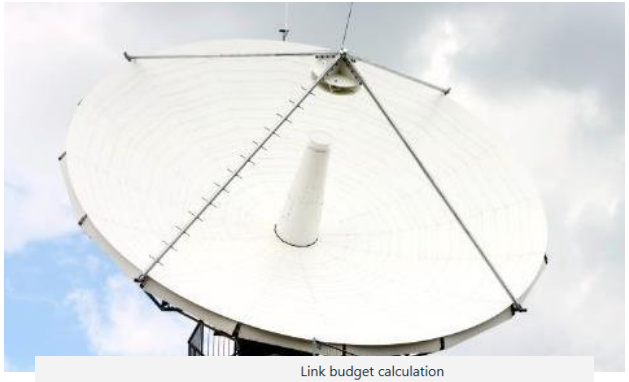
CHALLENGES FOR SATCOM LINKS

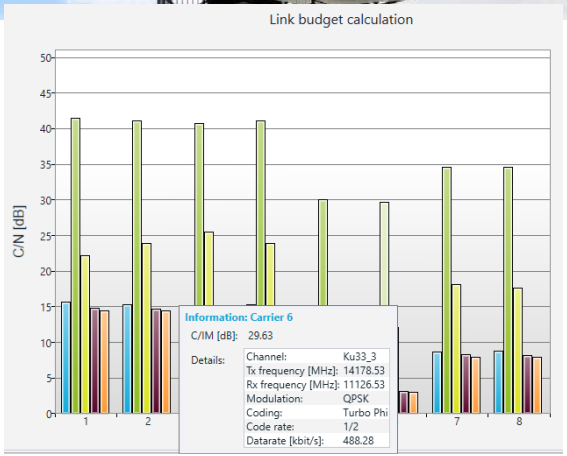


- Free space loss for GEO located satellite
  - 200dB for one path
  - Latency time 250msec for one way
- Weather interferences
  - Sun, rain, clouds
- Distortion/Intermods created by nonlinear components within the chain
  - Uplink amplifier
  - Transponder amplifier
- Footprints/coverage/directivity of antennas on the ground and within the satellite
- Sensitivity and noise behavior of the reception components within the link set-up
- And, very important: The required performance in terms of data-rate

TARGETS AND GOALS FOR SATCOM LINK PLANNING

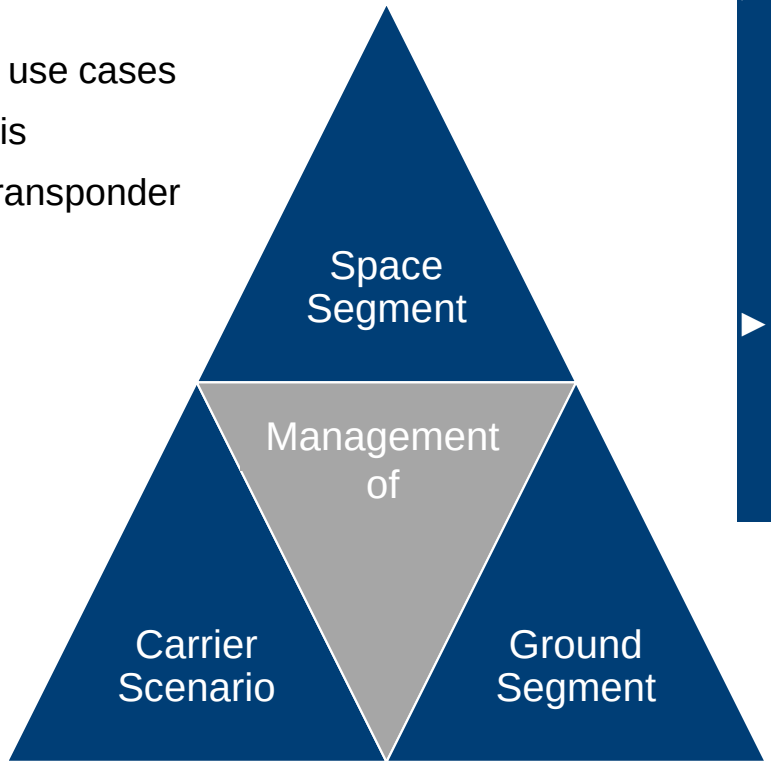
- Ensure a link with the optimization target for a defined data-rate and determine the C/N link budget
  - Footprint/coverage of the satellite
  - Consider weather conditions: clear sky, clouds and rain fall
  - QoS or service availability in percent
- Determine the required dish parameters like:
  - Size, Gain, Efficiency
- Amplifier calculation for the uplink
  - Intermod requirement
  - Number of carriers and total bandwidth





THE R&S GSASLP SATELLITE LINK PLANNER

- Parameters for individual use cases
- Satellite coverage analysis
- Optimizing satellite and transponder equipment



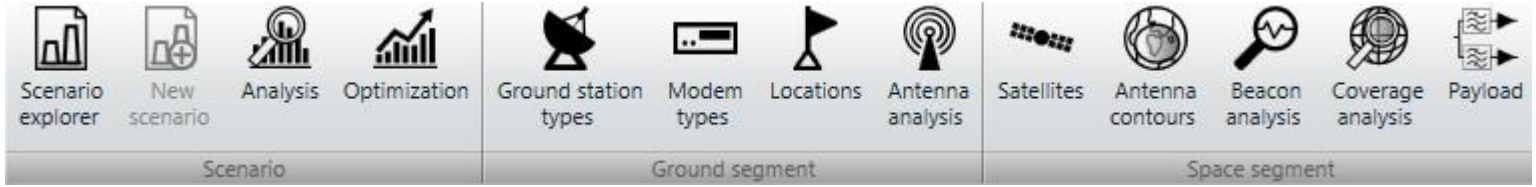
- The main purpose of the GSASLP is
  - the calculation
  - the optimization
  - the analysis

  of the link budget
- The input parameters are
  - technical specifications
  - environmental impairments

- Link budget calculation
- Earth station EIRP evaluation
- Intermodulation power density analysis

- Ground station management
- Ground station parameters of individual use cases
- Loss calculation

MAIN PARAMETERS



Description	ES Medium
HPA output power [W]	360
Transmitting antenna gain [dBi]	48.36
Tx reference frequency [MHz]	7501.131
Max. EIRP [dBW]	73.22
Minimal OBO [dB]	2
Tracking stability [dB]	0
EIRP stability [dB]	0
Receiving antenna gain [dBi]	48.36
Rx reference frequency [MHz]	7501.131
Antenna diameter [m]	4.3
Antenna efficiency [%]	
System G/T [dB/K]	30
Off-axis antenna gain [dBi]	0
Downconverter frequency [MHz]	0

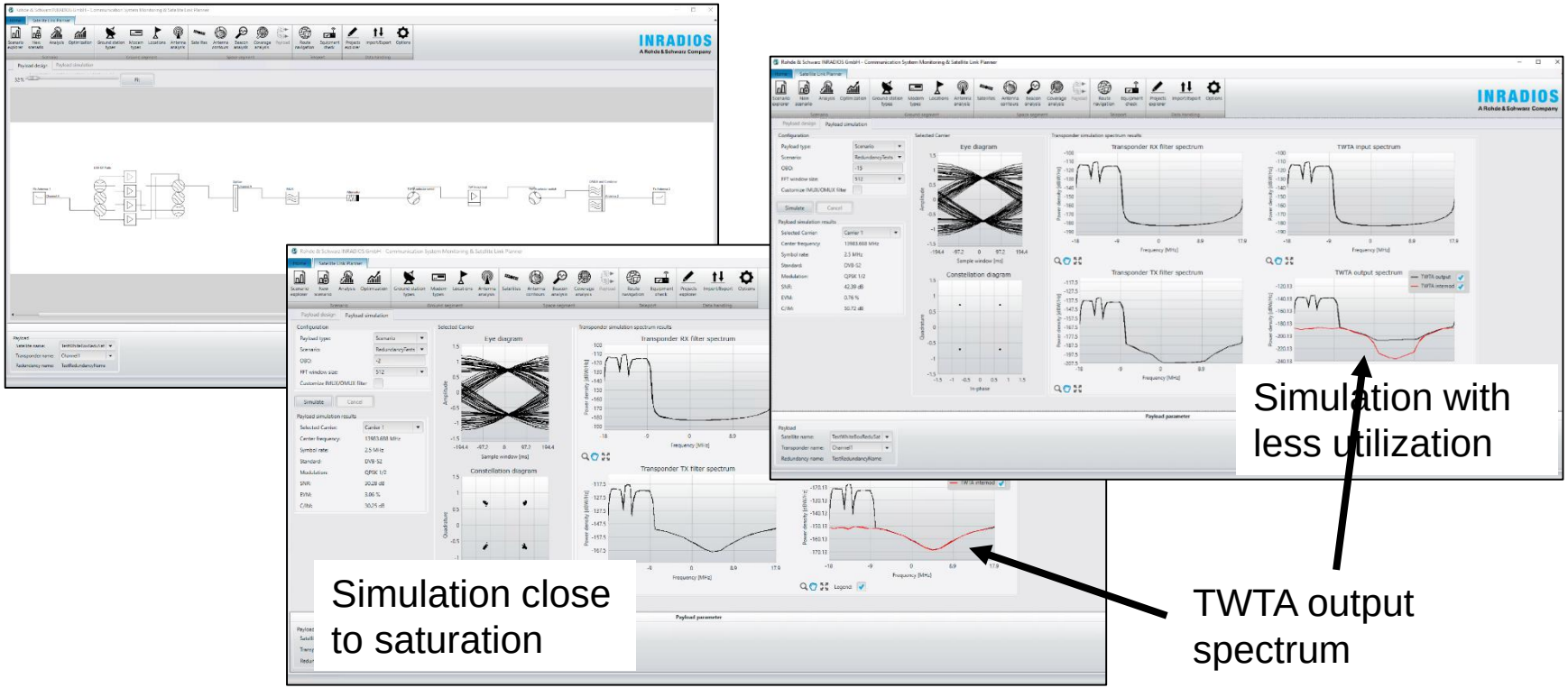
Manufacturer: PARADISE DATACOM
Modem type description: QUANTUM PD 25

Modulation	Coding	FEC rate
8PSK	TPC 2G	3/4
8PSK	TPC 2G	7/8
8PSK	TPC 2G	1
QPSK	TCM	2/3
QPSK	TCM	1
QPSK	TCM + RS	2/3
QPSK	TPC	7/8
QPSK	TPC 2G	1/2
QPSK	TPC 2G	3/4
QPSK	TPC 2G	7/8
QPSK	TPC 2G	1
QPSK	Viterbi	1/2
QPSK	Viterbi	3/4
QPSK	Viterbi	7/8
QPSK	Viterbi	1

Name: Arabsat5C
Satellite type: GEO
Geolocation: 20° 0' 0'' (E)

Transponder	UL beam	DL beam	UL frequency [MHz]	DL frequency [MHz]	Transponder type:
1	Spot1	Spot1	27000	17800	Transparent
10	Spot10	Spot10	27000	17800	Transparent
11	Wide	Wide	5400	3600	Transparent
2	Spot2	Spot2	27000	17800	Transparent
3	Spot3	Spot3	27000	17800	Transparent
4	Spot4	Spot4	27000	17800	Transparent
5	Spot5	Spot5	27000	17800	Transparent
6	Spot6	Spot6	27000	17800	Transparent
7	Spot7	Spot7	27000	17800	Transparent
8	Spot8	Spot8	27000	17800	Transparent
9	Spot9	Spot9	27000	17800	Transparent

PAYLOAD SIMULATION



LINK ANALYSIS

Scenario information

Scenario: Kastellaun

Satellite name: Astra1M
Configuration: NOMINAL
Transponder ID: Ku33_3
Transponder gain [dB]: 185.49
Transponder type: Transparent
Fixed OBO [dB]: 0

Ku33_3

SFD [dBW/m²]: -90

Carrier	Channel	Direction	Tx gs location/LEO	Rx gs location/LEO
1	Ku33_3	UL + DL	Kastellaun	Kairo
2	Ku33_3	UL + DL	Kairo	Kastellaun
3	Ku33_3	UL + DL	Kastellaun	Athen
4	Ku33_3	UL + DL	Athen	Kastellaun
5	Ku33_3	UL + DL	Kastellaun	Maradah
6	Ku33_3	UL + DL	Maradah	Kastellaun
7	Ku33_3	UL + DL	Kastellaun	Bergen
8	Ku33_3	UL + DL	Bergen	Kastellaun

Tx frequency [MHz]: 14171.38
Rx frequency [MHz]: 11119.38
UL Tx EIRP [dBW]: 38.4685
UL Tx EIRP density [dBW/Hz]: -25.95
Uplink rain:
Downlink rain:
Use ASI: deactivated
ASI uplink [%]: 0
ASI downlink [%]: 0
Analyze with FreCo: deactivated
Off-axis UL EIRP density [dBW/Hz]: -36
DL EIRP density [dBW/Hz]: -36

Single carrier signal | Multi carrier signal

Analyze | Save | Report | Transfer to CSM

Analysis overview

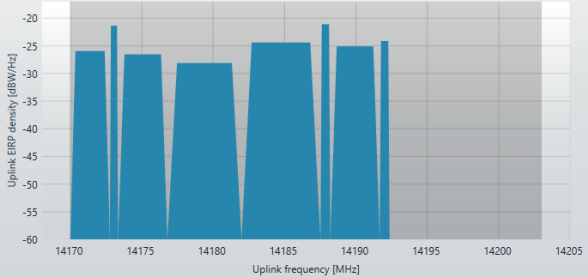
Carrier | Link budget

Carrier	1	2	3	4	5	6	7	8
Channel	Ku33_3	Ku33_3	Ku33_3	Ku33_3	Ku33_3	Ku33_3	Ku33_3	Ku33_3
Direction	UL + DL	UL + DL	UL + DL	UL + DL	UL + DL	UL + DL	UL + DL	UL + DL
Tx gs location	Kastellaun	Kairo	Kastellaun	Athen	Kastellaun	Maradah	Kastellaun	Bergen
Tx gs type	ES Medium	ES Large	ES Medium	ES Large	ES Medium	ES Large	ES Medium	ES Large
Tx modem type	M3 Series DVB-S2	M3 Series DVB-S2	M3 Series DVB-S2	M3 Series DVB-S2	SKYWAN IDU 7000	SKYWAN IDU 7000	SatLink 1000	SatLink 1000
Tx frequency [MHz]	14171.38	14173.05	14175.07	14179.39	14184.75	14187.86	14189.93	14192
Rx gs location	Kairo	Kastellaun	Athen	Kastellaun	Maradah	Kastellaun	Bergen	Kastellaun
Rx gs type	ES Large	ES Medium	ES Large	ES Medium	ES Large	ES Medium	ES Large	ES Medium
Rx modem type	M3 Series DVB-S2	M3 Series DVB-S2	M3 Series DVB-S2	M3 Series DVB-S2	SKYWAN IDU 7000	SKYWAN IDU 7000	SatLink 1000	SatLink 1000
Rx frequency [MHz]	11119.38	11121.05	11123.07	11127.39	11132.75	11135.86	11137.93	11140
UL Tx EIRP [dBW]:	38.47	36.25	38.84	39.03	43.02	37.31	40.3	34.27
DL Tx EIRP [dBW]:	50	50	50	50	50	50	50	50

UPLINK

GS/LEO	GS type/LEO	Carrier count	Tx EIRP(max) [dBW]	Tx-EIRP(sum) [dBW]	Min OBO [dB]	Δ OBO [dB]
Athen	ES Large	1	81.64	39.03	-4	-38.61
Bergen	ES Large	1	81.65	34.27	-4	-43.38
Kairo	ES Large	1	81.64	36.25	-4	-41.39
Kastellaun	ES Medium	4	78.75	46.58	-2	-30.18
Maradah	ES Large	1	81.65	37.31	-4	-40.34

Uplink EIRP density

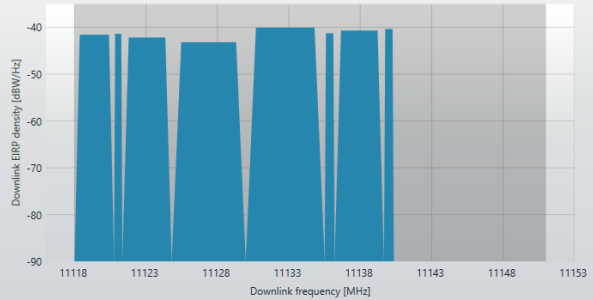


DOWNLINK

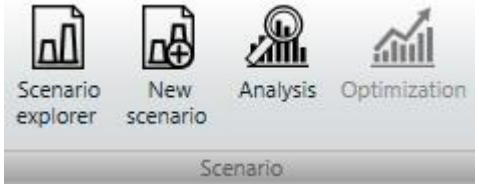
MPM	Gain [dB]	IBO [dB]	OBO [dB]	Output EIRP [dBW]	PEB [MHz]
Default_Unlinearized	192.45	-23.31	-16.35	34.65	0.77

Channel	Total gain [dB]	Bandwidth [MHz]	SFD [dBW/m^2]
Ku33_3	192.45	22.35	-90

Downlink EIRP density



LINK OPTIMIZATION



Carrier	1	2	3	4	5	6	7	8
Channel	Ku33_3	Ku33_3	Ku33_3	Ku33_3	Ku33_3	Ku33_3	Ku33_3	Ku33_3
Tx gs location	Kastellaun	Kairo	Kastellaun	Athen	Kastellaun	Maradah	Kastellaun	Bergen
Tx gs type	ES Medium	ES Large	ES Medium	ES Large	ES Medium	ES Large	ES Medium	ES Large
Tx modem type	M3 Series DVB-S2	M3 Series DVB-S2	M3 Series DVB-S2	M3 Series DVB-S2	SKYWAN IDU 7000	SKYWAN IDU 7000	SatLink 1000	SatLink 1000
		14173.05	14175.07	14179.39	14184.75	14187.86	14189.93	14192
		Kastellaun	Athen	Kastellaun	Maradah	Kastellaun	Bergen	Kastellaun
		ES Large	ES Medium	ES Large	ES Medium	ES Large	ES Medium	
		M3 Series DVB-S2	M3 Series DVB-S2	SKYWAN IDU 7000	SKYWAN IDU 7000	SatLink 1000	SatLink 1000	
		11123.07	11127.39	11132.75	11135.86	11137.93	11140	

Benchmark is the power equivalent bandwidth

Proposal: Quick power efficient o

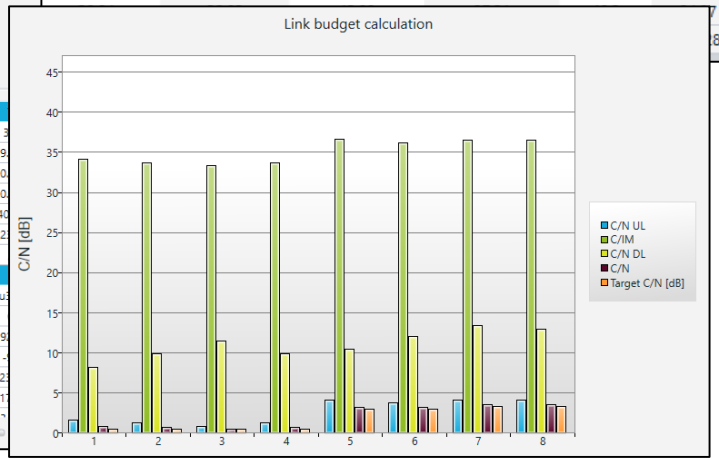
Could close 8 / 8 links.

TWTA output power [dBW]: 33.97 TWTA output power [%]: 1.98

PEB equilibrium: 35.27

Channel	Bandwidth [MHz]	Bandwidth [%]
Ku33_3	23.071	69.91

Carrier	1	2	3	4	5	6
Used bandwidth [MHz]	3.3	0.82	4.12	4.94	5.27	0.66
Bandwidth [%]	9.99	2.5	12.48	14.98	15.98	2
Current PEB [MHz]	0.04	0.01	0.04	0.05	0.1	0.01
Percentage of power output [%]	0.11	0.03	0.11	0.15	0.31	0.04
Ground station Tx EIRP [dBW]	38.24	35.38	38.42	39	43.07	37.18
Downlink EIRP [dBW]	21.4	15.02	21.59	22.8	25.93	16.54
Margin DL EIRP FreCo [dB]	/	/	/	/	/	/
Transponder						
Channel	Ku33_3	Ku33_3	Ku33_3	Ku33_3	Ku33_3	Ku33_3
Transponder gain step	0	0	0	0	0	0
Eff. transponder gain [dB]	192.44	192.44	192.44	192.44	192.44	192.44
SFD [dBW/m²]	-90	-90	-90	-90	-90	-90
IBO [dB]	-23.98	-23.98	-23.98	-23.98	-23.98	-23.98
OBO [dB]	-17.03	-17.03	-17.03	-17.03	-17.03	-17.03



BETTER SAFE THAN SORRY

- 1,700 satellites launched every year by 2030
- Frequency spectrum is a limited good
- National licenses differ from each other
- Local impairments can show negative effects elsewhere
- Effects between terrestrial and none-terrestrial networks
- The list of bad news is endless…

… see what's our answer

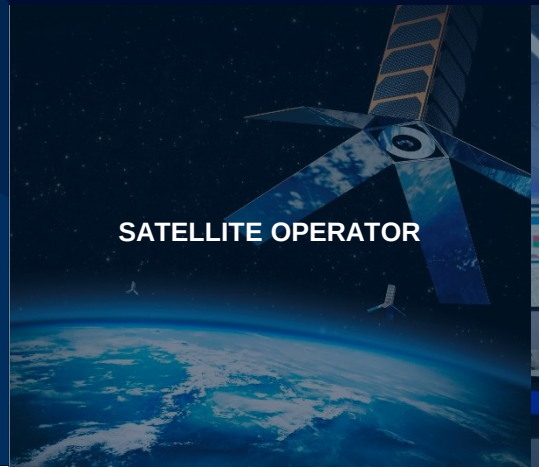
COMMUNICATION SYSTEM MONITORING (R&S®GSACSM)

SATCOM MONITORING

FOR CONTROL OF SATELLITE COMMUNICATION OPERATIONS

- Complexity is increasing because of
  - Missing standards
  - More players in SatCom
  - Mission-critical links
  - Increasing interference
- The task is to monitor the failure-free communication and to determine impairments in operation
- Our solution
  - CSM monitoring software
  - MSR4 satellite receiver

Our customers



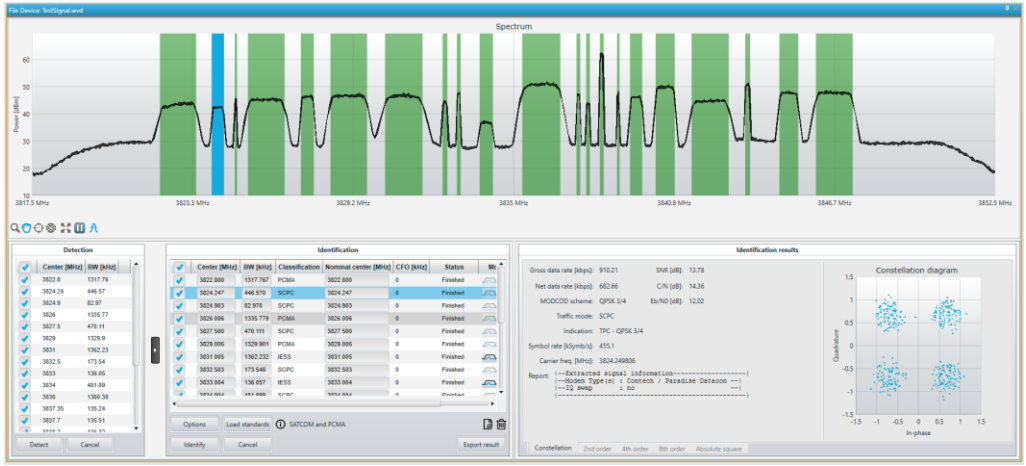
SATCOM PORTFOLIO

- R&S®GSACSM combines several features in one software-suite
  - Classic spectrum analyzer functions
  - Trapping systems
  - Advanced signal detection
  - Identification algorithms

- R&S®MSR4 as multipurpose satellite receiver with a unique SWaP concept for different use cases
  - As high-performance RF frontend for software defined radio solutions
  - Flexible feature configuration by software licenses only

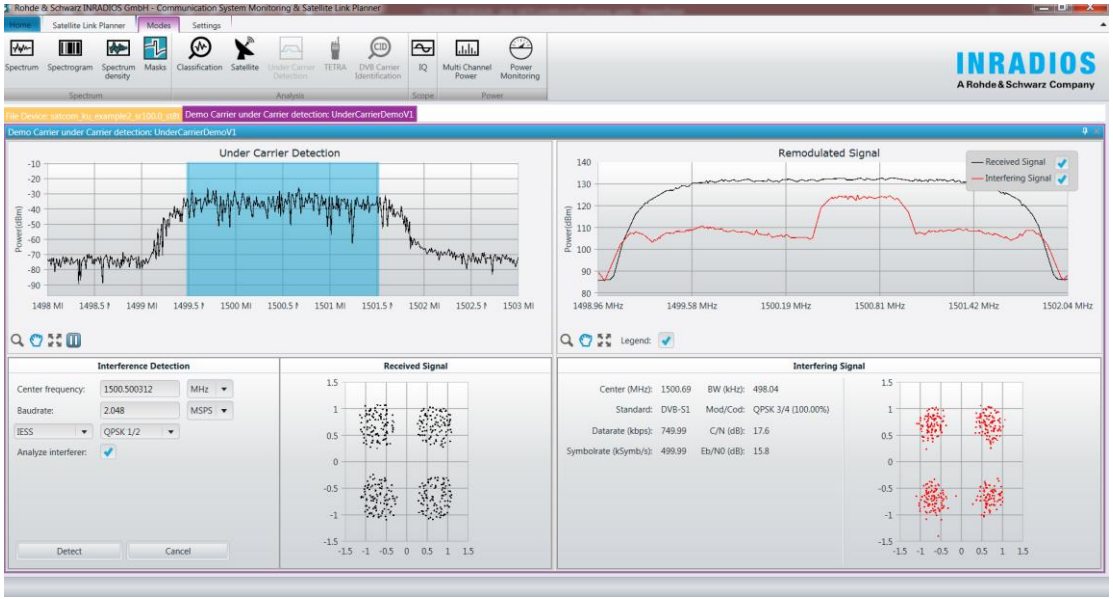
SIGNAL ANALYSIS

- Automatic detection of carriers in the spectrum
- Visualization of constellation diagrams and signal parameters
- All common types of modulation supported (QPSK, 8QAM, 8PSK, 32APSK, etc.)
- All common satellite standards supported (DVB-S, DVB-S2, IESS, etc.)
- Detection of carrier in carrier signals



SATCOM INTERFERENCE HUNTING

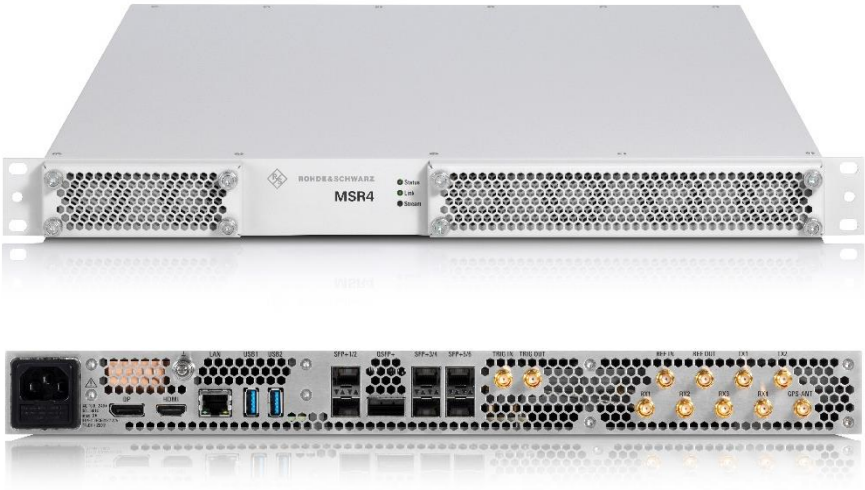
- Source for interference might be
  - other satellite signal
  - terrestrial signal
- Demodulation, decoding and subtraction of wanted signal
- Underlying interfering signal is displayed and classified



FACT SHEET

- Small form factor with
  - 4 RF inputs
  - 2 RF outputs

Rx and Tx are tunable and operate simultaneously in L-Band with 200 MHz real-time bandwidth each

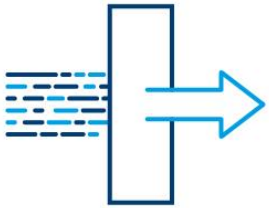


- 10 Gbit/s streaming output for each input

- Web-based graphical user interface

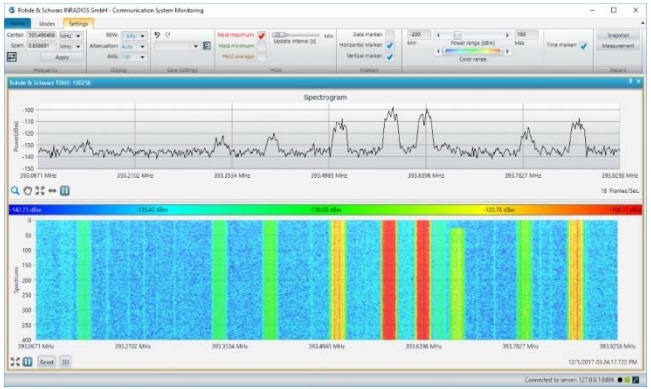
- Software Defined Radio for flexible applications with high performance analog frontend

FEATURES



- IQ Streaming for software defined radio applications
  - Up to 4x 200MHz Rx simultaneously to an external device
  - Up to 2x 200MHz Tx simultaneously
    - 1x from 10Gbit/s Ethernet to Tx
    - 1x from Rx to the internal storage device

- R&S GSACSM Server
  - 4x 200MHz sensors
  - SatCom monitoring with multiple functions
  - Autonomous detection and classification of SatCom signals



Thank You!

Benjamin Jungbauer

ROHDE & SCHWARZ
SOLUTION MANAGER SATCOM

BENJAMIN.JUNGBAUER@ROHDE-SCHWARZ.COM