ASMS 2025 SPSC 2025 Sitges, 26-28 February 2025

DVB STANDARD SUPPORT OF NGSO SYSTEMS

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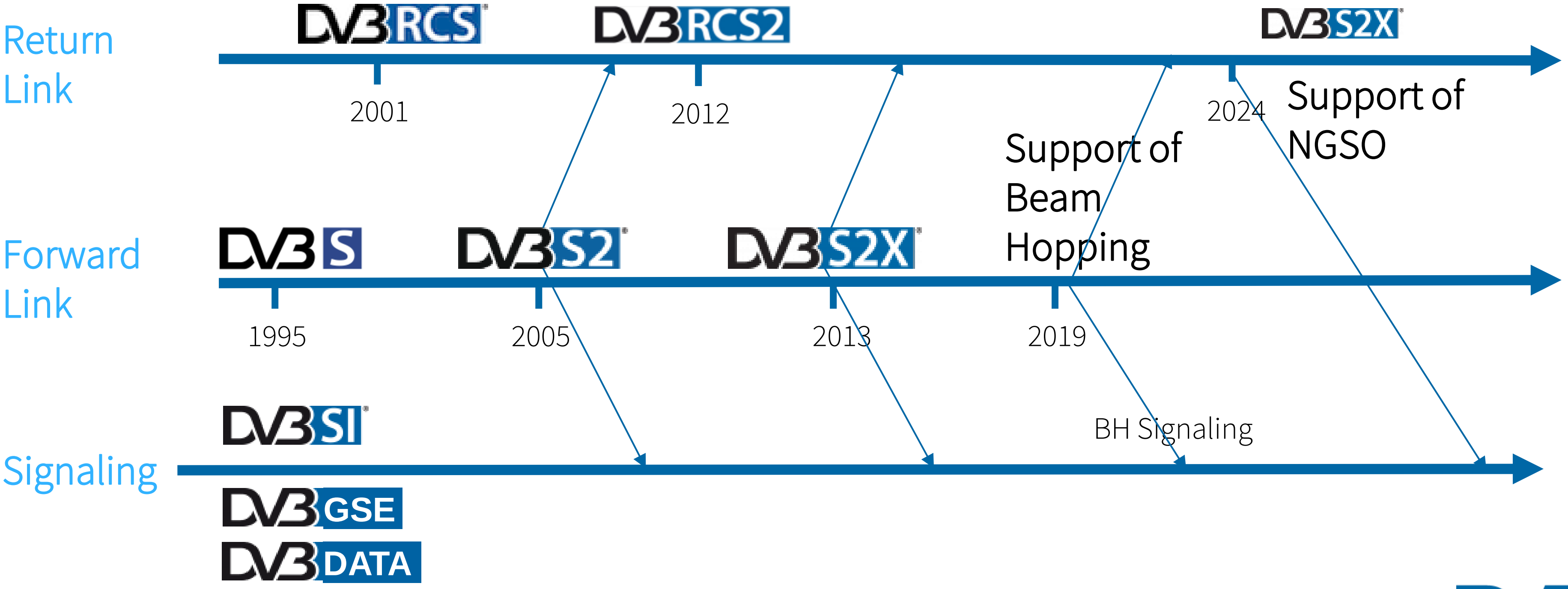
- Status
- Commercial requirements
- Modification of the specifications
- Analyses, simulations & results
- Conclusions

DVB Standards for Satellite Communications

Time line and history



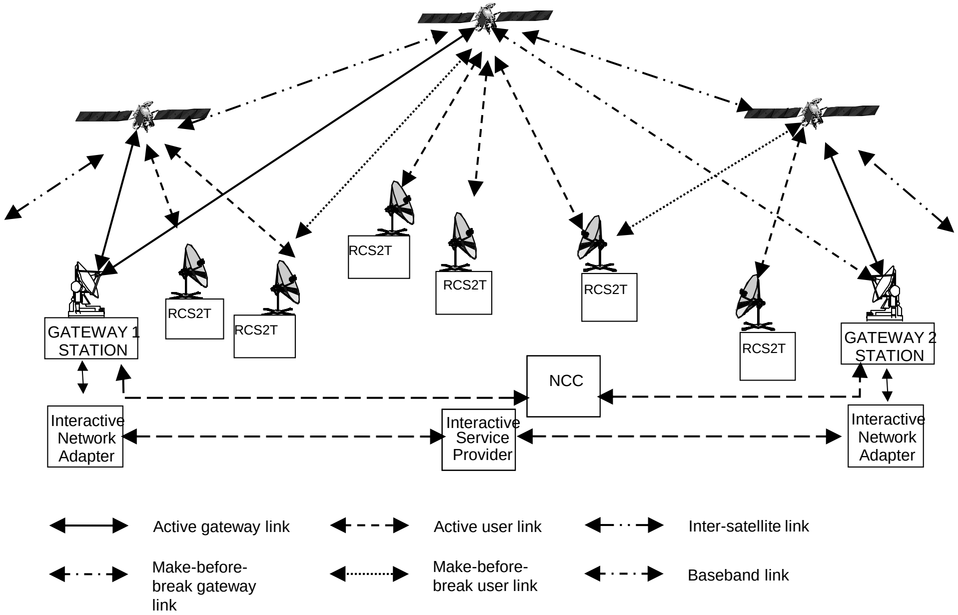
DVB Standards for Satellite Communications

Status (February 2025)

- RCS2
  - Part 1: Overview: Published as BlueBook A155-1r3 TS 101 545-1 v1.4.1
  - Part 2: Lower Layers: Published as BlueBook A155-2r4 EN 301 545-2 v1.5.1
  - Part 3: Higher Layers: No change
  - Part 4: User guidelines for Lower layers: On-going EN 301 545-4 vx.x.x
  - Part 5: User guidelines for higher layers: No change

- Signaling Specifications
  - DVB-GSE LLC (BH & NGSO) published as BlueBook A116-2r3 TS 102 606-2 v1.3.1
  - DVB- SI (BH &NGSO): Conditional approval as BlueBook A038r17 EN 300 468 v1.19.1
  - DVB-DATA Approval for publication as BlueBook A027r5 EN 301 192 v1.8.1

Reference Scenario of a DVB-RCS2 NGSO satellite network: Context.



- Forward & return link
- broadband application
- Using VSAT or ESA antennas

Waveforms for NGSO- Basic Needs

- Robust acquisition
- Robust tracking, Doppler tolerant
- Spectrally efficient
- Low Peak-to-Average Power Ratio
- Supports flexible and variable demand
  - forward link
  - Flexible bandwidth and time allocation on the return link
- High Technological Readiness Level
- Standard based- for open competitive market
- Support of multi-satellite constellations

- ➢ Superframe header ✓
- ➢ Regular header & pilot structure ✓
- ➢ Referenced to Shannon ✓
- ➢ xPSK modulation, wide carriers ✓
- ➢ Frame by frame resource allocation
  - S2X ACM, beam-Hopping
  - RCS2, MF-TDMA ✓
- ➢ Large installed base for satellites (GEO, VSAT) ✓
- ➢ Available now published in DVB and ETSI ✓
- ➢ The subject of this presentation ✓

Commercial Requirements

- System Enhancements for NGSO
  - Satellite Positioning Format, Support of Make Before Break Handover, Support of Beam-Hopping
- Return Link Capability Enhancement
  - Higher symbol rate, Large size PDU, Lower Roll-off, Support DVB-S2X on the Return Link
- Analyses and Simulations
  - Performance in Doppler, operation without GNSS, System level simulations RCS2 – S2x – 5G NTN …

System Enhancements for NGSO

Alternative positioning formats

2022 version :

- TLE
- Orbital parameters

Two-Line Element

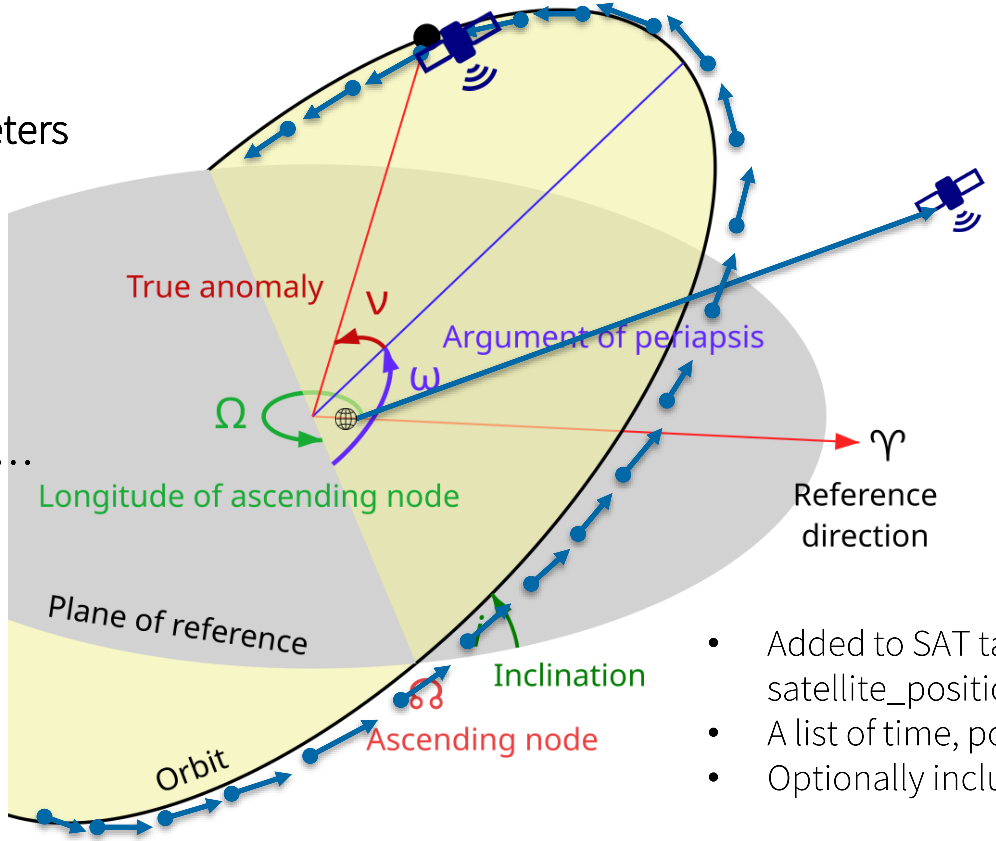
2024 version :

- OEM Format*
- Direct Orbit

  $t, x, y, z, v_x, v_y, v_z, \ldots$

Orbit Ephemeris Message

* CCSDS 502



GEO Satellite

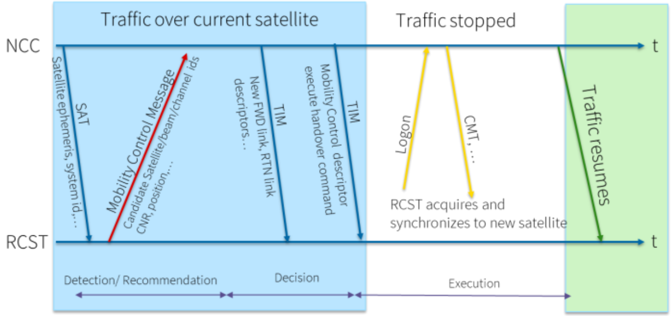
- Longitude
- SPT: X,Y,Z

- Added to SAT table in DVB-SI as satellite_position_v3
- A list of time, position and velocity points
- Optionally includes acceleration and covariance

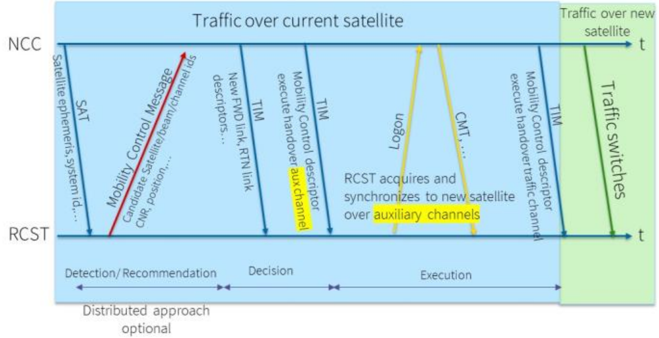
System Enhancements for NGSO

Support of MBB and BBM Handover

Handover Procedure – Break before Make



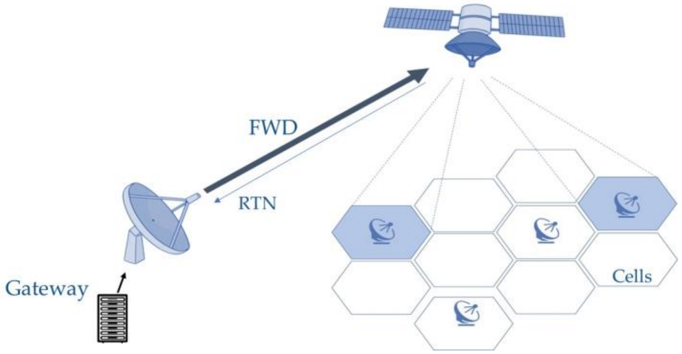
Handover Procedure – Make before Break



- Enabled reference to auxiliary channel for Make Before Break handover
- Added signaling to enable satellite handover
  - Replace Beam_ID with Satellite_ID + Beam_ID
- Kept unchanged, mobility management principles (distributed/ centralized approaches)

System Enhancements for NGSO

Support of Beam Hopping on forward link



- Implemented in v1.4.1 of RCS2-LL specification
- Main changes:
  - Satellite Forward Link Descriptor: **Satellite Delivery System S2Xv2**
    - Necessary parameters of S2X- Annex E (superframes)
  - Broadcast Table: **Satellite Access Table (SAT)**
    - Satellite ephemeris data
    - Beam-hopping Time plan
    - ..
  - **Logon** and **Control** Burst content
    - Added RCS Terminal capability signaling

Commercial Requirements

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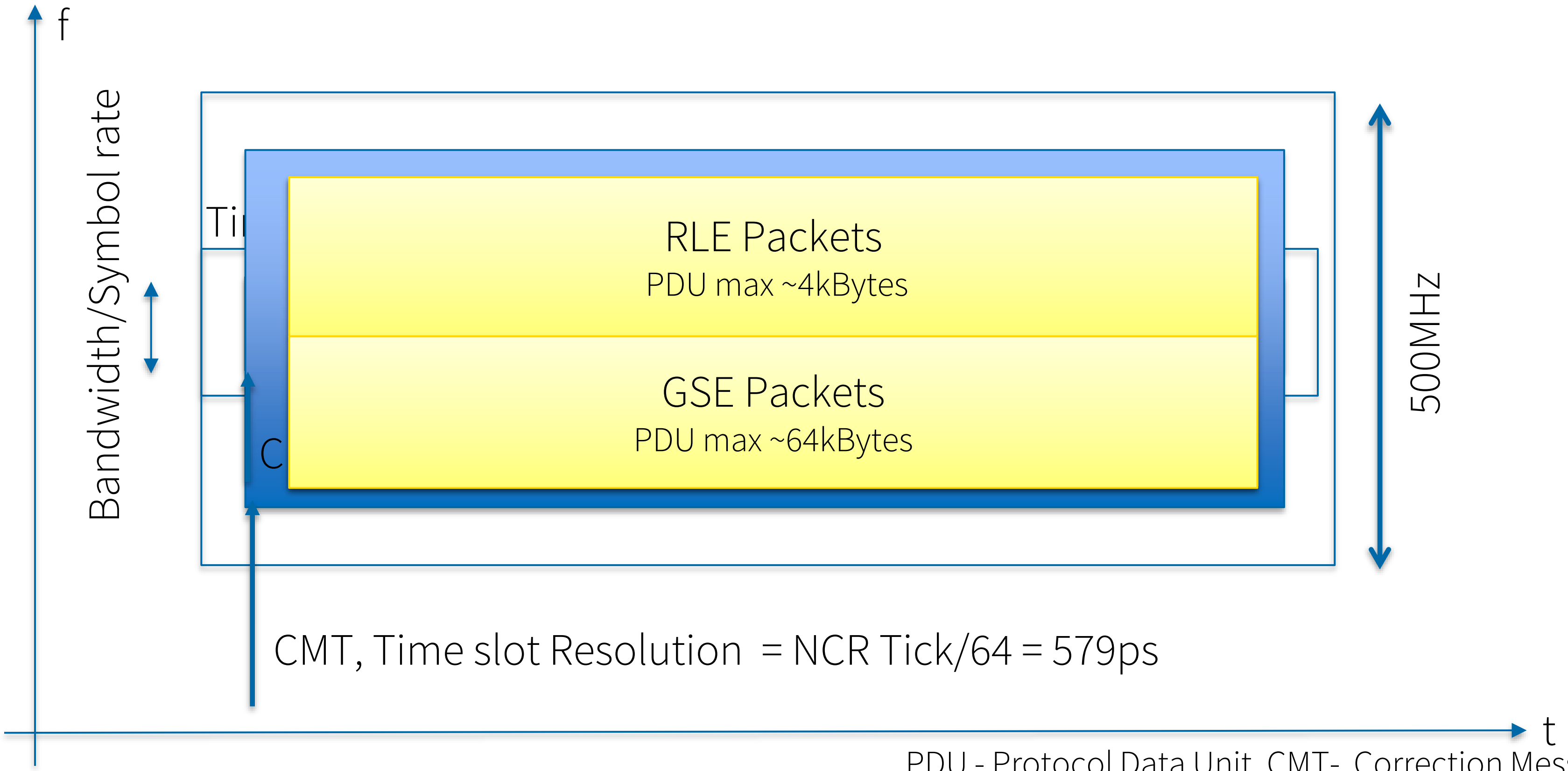
Return Link Capacity Enhancement

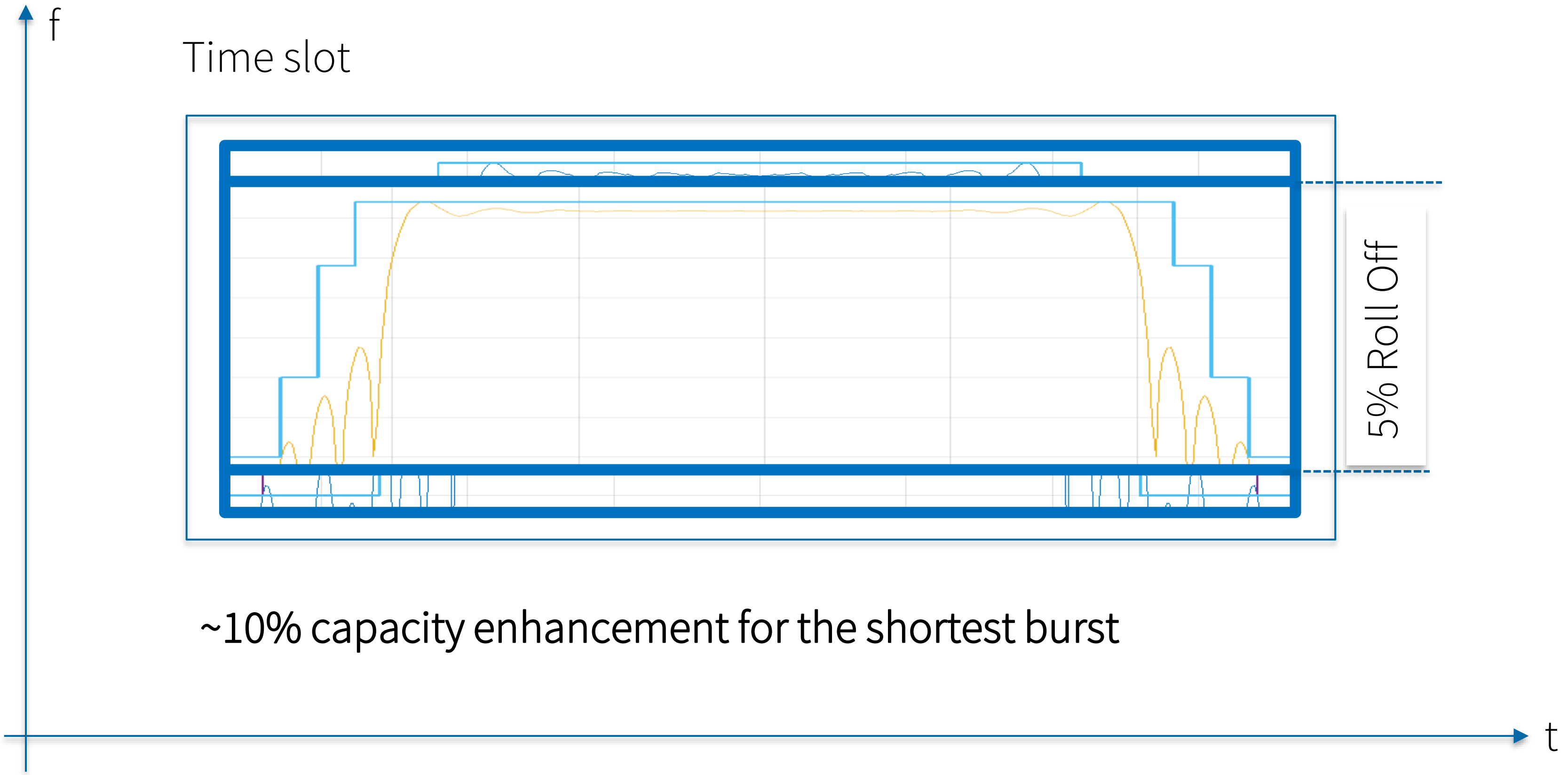
symbol rate and protocol enhancements



PDU - Protocol Data Unit, CMT- Correction Message Table

Return Link Capacity Enhancement

Roll off

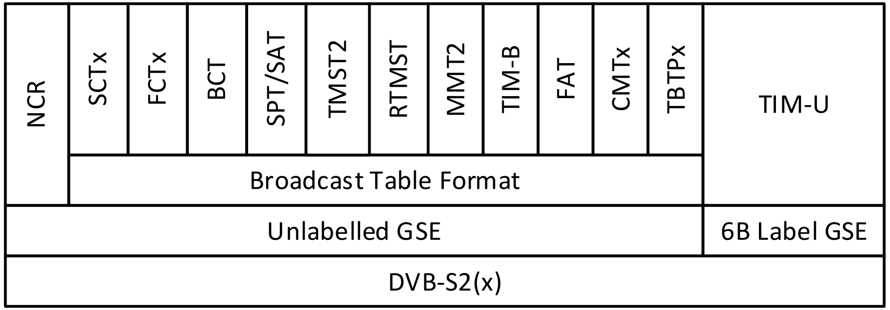


~10% capacity enhancement for the shortest burst

Return Link Capacity Enhancement

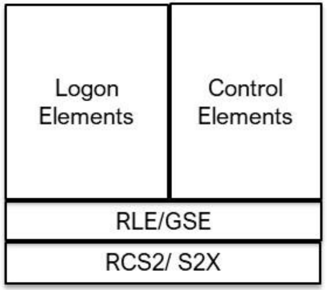
DVB-S2X on the Return Channel

- Enable any S2X frames or superframes – unmodified
  - Higher efficiency - larger frames
  - Reuse of existing S2X eco-system
- Modes:
  - Bursts within the MFTDMA
  - Non persistent continuous mode
  - Persistent continuous mode
- Modcod setting
  - Either by the hub, using the new BCT2/FCT3/TBTP3/RTMST tables
  - By the RCST, using Physical Layer Signaling (PLS)
- Replaces existing Continuous Carrier mode



- New versions for SCT, FCT, SAT, CMT, TBPT
- Additional Table: RTMST
- Back compatible to RCS2

- Logon
  - Capability support
- Control
  - High volume capacity requests
  - MBB mobility management
  - Satellite HO support



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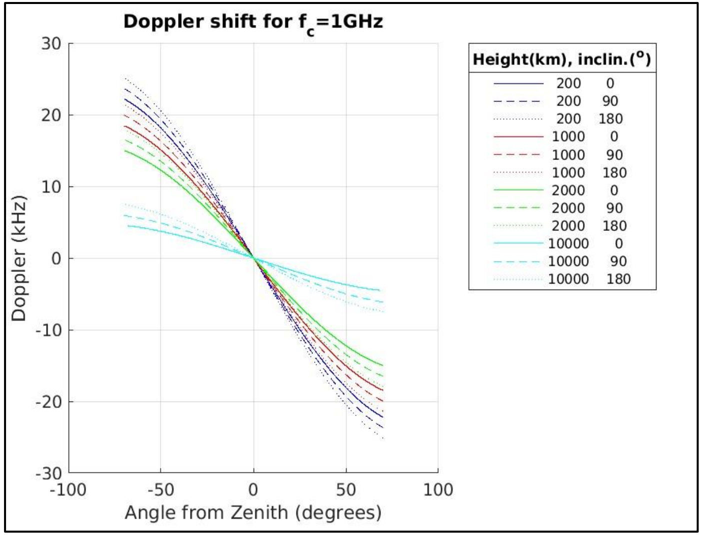
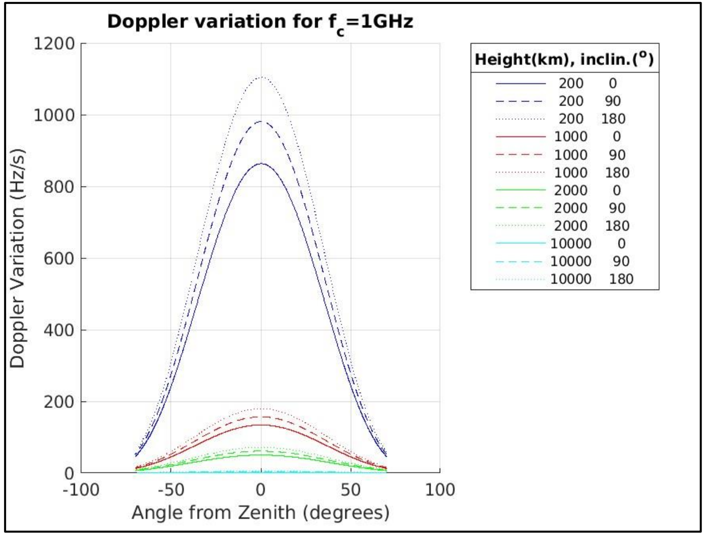
Analyses and Simulations

The Doppler Shift and Variation





Circular orbits

Heights: 200- 10000 km

Inclinations: 0, 90, 180

Terminal at Lat = 0

Orbit overhead

- Doppler effects largely depend on satellite altitude and elevation
- With knowledge of Time, Position and ephemeris data, Doppler compensation can easily be calculated and applied

Analyses and Simulations

Operation without GNSS

- In general, GNSS is required for:
  - Accurate synchronization
  - Accurate Remote terminal location
- For NGSO constellation:
  - Antenna pointing
  - Doppler compensation
  - Calculation of propagation delay

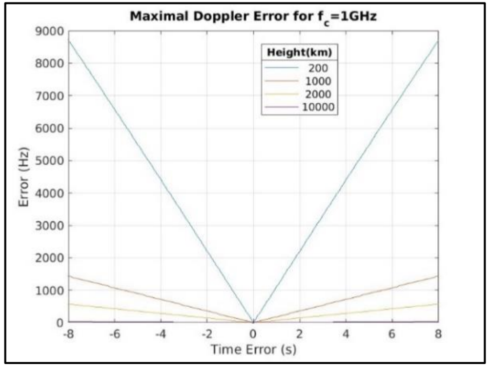
Analyses and Simulations

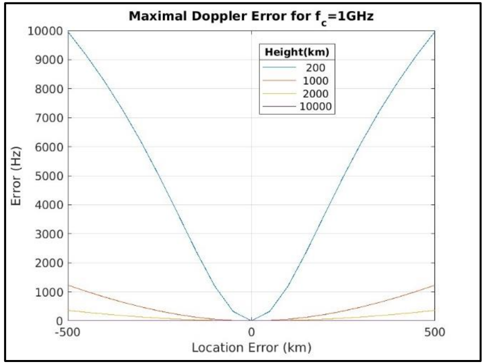
Operation without GNSS, compensation for PNT Error

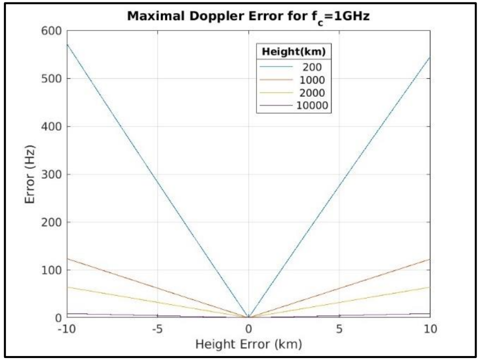
Time

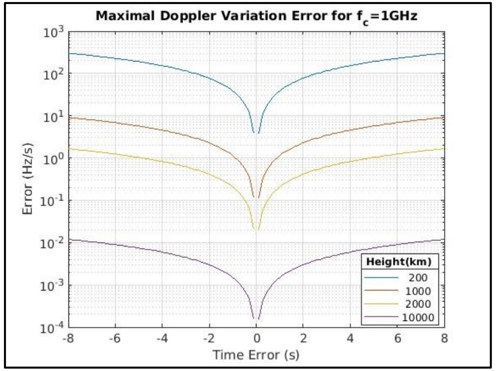
Location

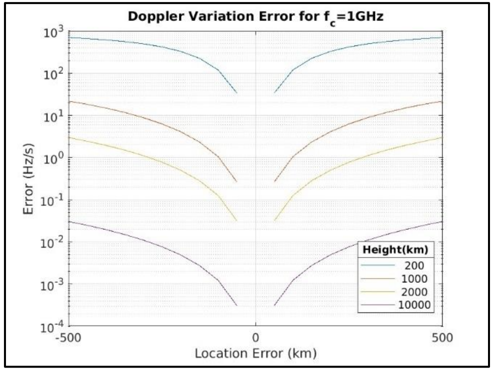
Altitude

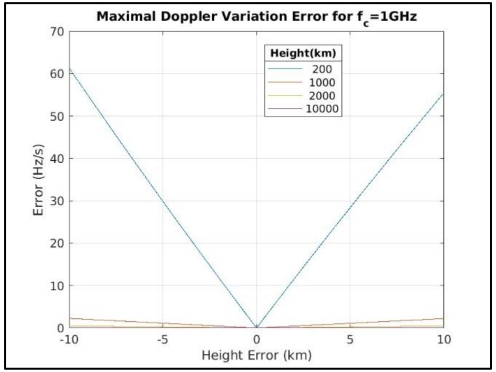












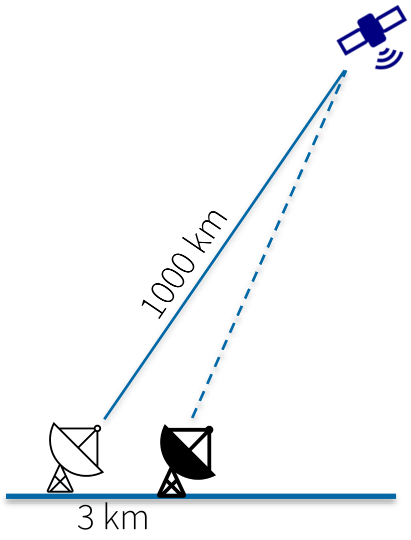
The impact of timing and positional error was assessed for Doppler shift and drift

Analyses and Simulations

Operation without GNSS, Initial Network Entry

- Available information:
  - Satellite trajectory
  - “Startup channel” parameters
  - Location error – 3km
  - Time of day clock error: 3 sec

- Resulting Errors (1000 km satellite)
  - Pointing error: 0.18^0
  - Doppler compensation error: 16kHz (Ka band)
  - Timing errors > 3 sec



Analyses and Simulations

Operation without GNSS, means to Acquire Synchronization

- NCR Messages – Propagation Delay Measurement
  - resolution: 37ns, accuracy: 5ppm
- Time association message associates Time of Day and NCR
- Satellite trajectories using OEM format (assume high accuracy)
- DVB-S2X superframes with extended preamble, postamble and pilots- For accurate time estimation

$$\sigma_t \geq \frac{1}{B\sqrt{N_{pre}\frac{E_s}{N_0}}}$$

DVB

Analyses and Simulations

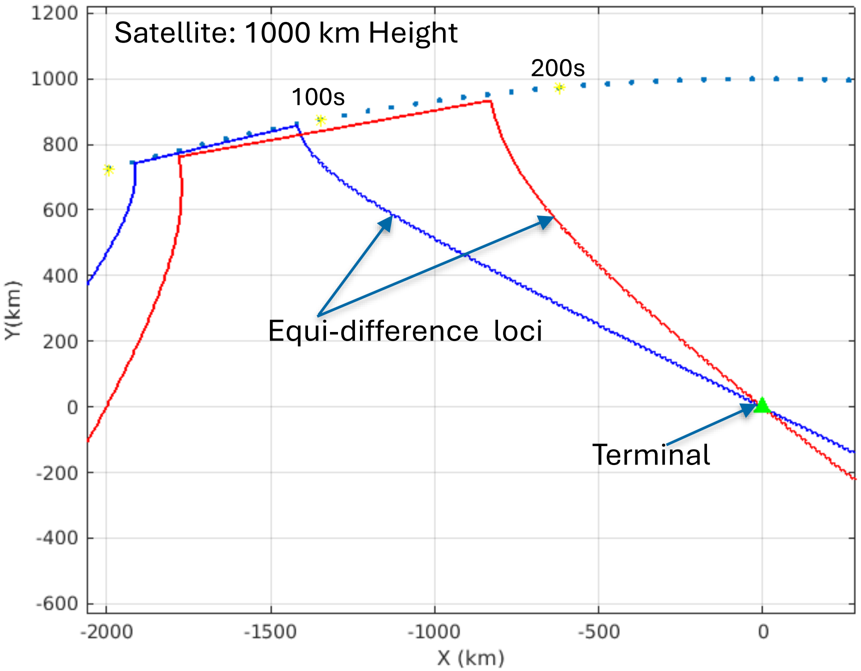
Operation without GNSS, Operation Procedure

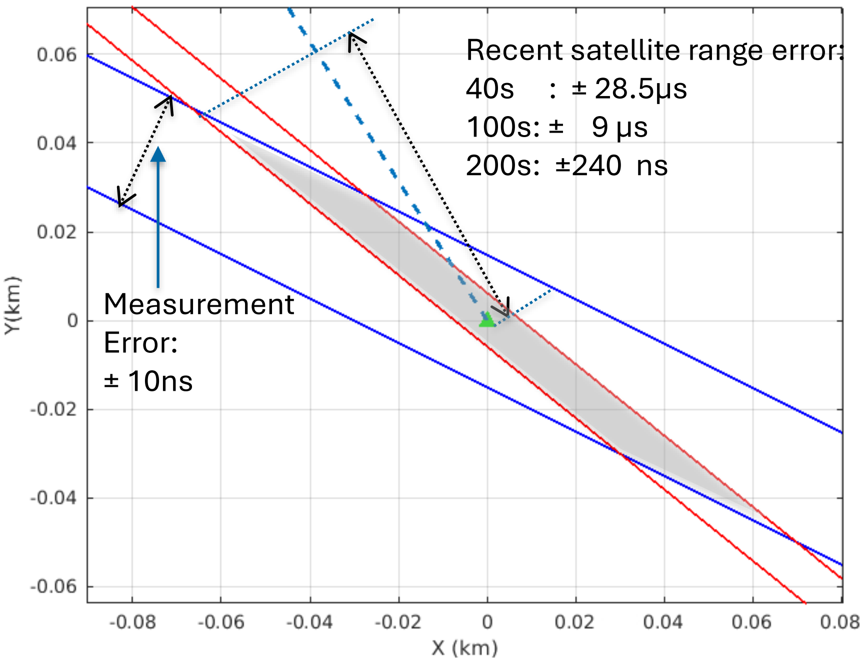
- Initial Procedure
  - Search and acquisition
  - Receiving SAT and NCR
  - Estimate pseudo range
    - For other NCR packets along the satellite trajectory
  - Extract the unknown location and bias
- Position correction
  - Using the satellite trajectory as an anchor- improve location and extract the propagation delay
  - Synchronize remote terminal NCR clock to the satellite
    - With CMT– Correction Message – resolution 579ps, Improve RCST location
  - Using other satellite trajectories- correct remote terminal position
- Doppler residual error = ~2.5%

$$t_{pd}(i) = [T_r(i) + b] - T_t(i) = \frac{1}{c}\left|\boldsymbol{r_{sat}}[T_t(i)] - \tilde{\boldsymbol{r}}\right|$$

Analyses and Simulations

Operation without GNSS, Location Accuracy-Analysis





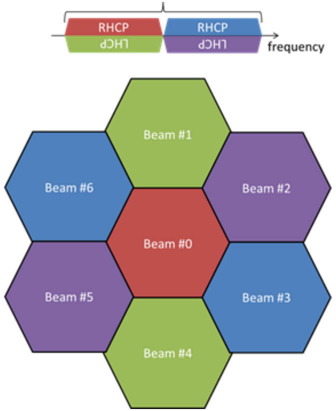
- Conclusion: Acquisition, synchronisation and Network entry can be reliably obtained without GNSS assistance using DVB waveforms.
  - And can even provide PNT estimations

System simulation RCS2 – S2x – 5G NTN …

Simulation scenario

- Satellite simulators: SNS3 and ALIX NR NTN/TN
- Link budget parametrization based on 3GPP NTN specifications of LEO-600 satellite with Frequency Re-use Factor 2+2 (FRF2+2), 500 MHz bandwidth per beam
- The traffic model used in the simulation is the full buffer traffic model, which generates traffic at the RLC/LLC layer i.e. the RLE or GSE layer for DVB

FRF2+2 re-use scheme, using 2 dual-polarized carriers



Cellular deployment of the simulated cells

Terminal characteristics 3GPP VSAT

Characteristics	VSAT
Frequency band	Ka-band (i.e., 30 GHz UL and 20 GHz DL)
Antenna type and configuration	Directional with 60 cm equivalent aperture diameter
Polarization	circular
Rx Antenna gain	39.7 dBi
Antenna temperature	150 K
Noise figure	1.2 dB
Tx transmit power	2 W (33 dBm)
Tx antenna gain	43.2 dBi

Satellite characteristics 3GPP Set-1

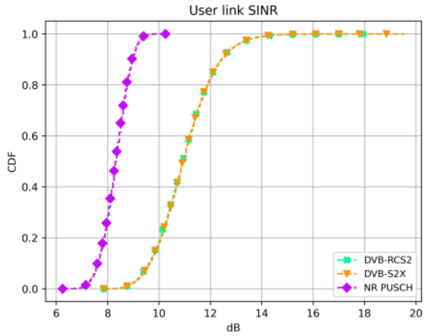
Satellite orbit		LEO-600
Satellite altitude		600 km
Payload characteristics for DL transmissions		
Equivalent satellite antenna aperture	Ka-band (i.e. 20 GHz for DL)	0.5 m
Satellite EIRP density		4 dBW/MHz
Satellite Tx max Gain		38.5 dBi
3dB beamwidth		1.7647 deg
Satellite beam diameter		20 km
Payload characteristics for UL transmissions		
Equivalent satellite antenna aperture	Ka-band (i.e. 30 GHz for UL)	0.33 m
G/T		13 dB K^{-1}
Satellite RX max Gain		38.5 dBi

System simulation RCS2 – S2x – 5G NTN …

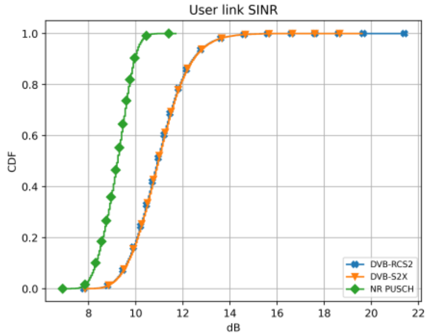
Simulation results

Simulations with AWGN channel and Doppler

Doppler compensation 97.5%



Doppler compensation 99.3%



- The DVB waveforms (both RCS2 and S2X) enjoy an advantage of about 3dB in SINR (at the 80% percentile) over NR PUSCH with Doppler compensation at 97.5%, reducing to 2dB with DC at 99.3 (eq. 0.1ppm)%
- NR PUSCH is more sensitive to Doppler effects.
- Explained by single carrier format of DVB and the use of roll-off factors and carrier spacing, effectively preventing inter-carrier interference.
- For comparison, the OFDM waveform used by NR suffers from a loss of orthogonality between the subcarriers, induced by the frequency shift.

CDF – Cumulative Distribution Function NR PUSCH – New Radio Physical Uplink Shared channel

System simulation RCS2 – S2x – 5G NTN …

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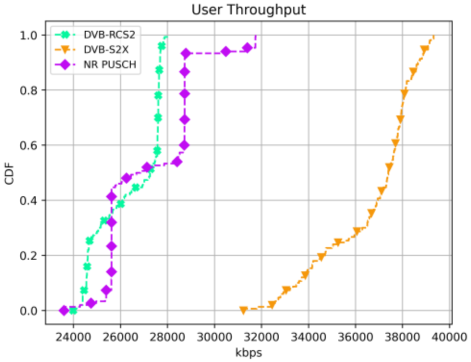

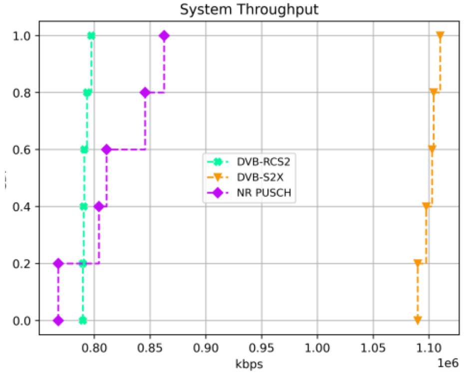

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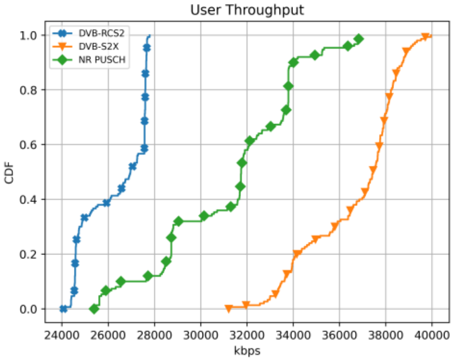
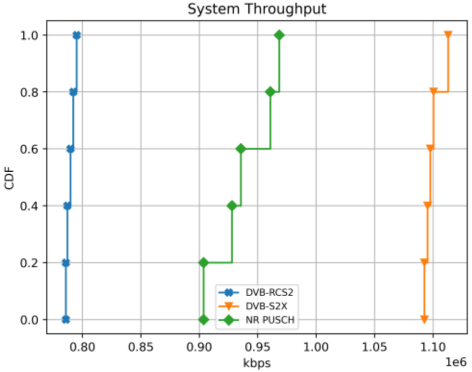




- NR PUSCH shows an advantage in throughput over the RCS2 waveform.
- On the other hand, the DVB-S2X waveforms, show a clear advantage over both RCS2 and NR PUSCH.
- This is mainly facilitated by highly spectrally efficient MODCODs, with a fine granularity, and the high-capacity frames, providing a very small overhead.

Wrapping up

- Technology readiness
- Conclusions
- Takeaways

Technology Readiness

SatixFy

SatixFy's Ground Products & Chips

Sx3000
500MHz DVB-S2X
SDR Modem chip

Sx3099
1GHz DVB-S2X
8 SDR Modems chip

Beat
Ku-band RFIC
Ka-band RFIC

Prime 1.0
True Time Delay
digital beamformer

Terminals, Hubs & Gateways

High-end
Mobile Terminal

Inflight Connectivity
(IFC) System

COTM
ESMA Terminal

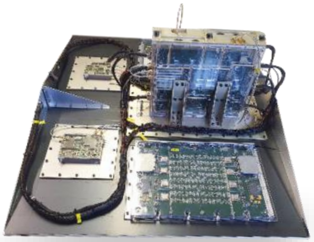
Broadband
Modem

Technology Readiness

SatixFy's Space Products & Chips

Sx4000
Space grade
payload processor chip

Prime 2.0
Space grade
digital beamformer



Satellite
Payloads

DRA /PAFR Antenna

for space

Technology Readiness

EASii IC

EZiD211 (Oxford-2)

V1 in Mass Production since Q1 2024

V2 in mass production since December 2024
- Beam Hopping enabled

Available NOW !

EZiD211 (Oxford-2)
Low Power: 3 to 5 Watts
Dual channel Rx 500Msymbol/s
DVB-S2x
Single return channel RCS2, S2X & IQ streamer

Evaluation Board

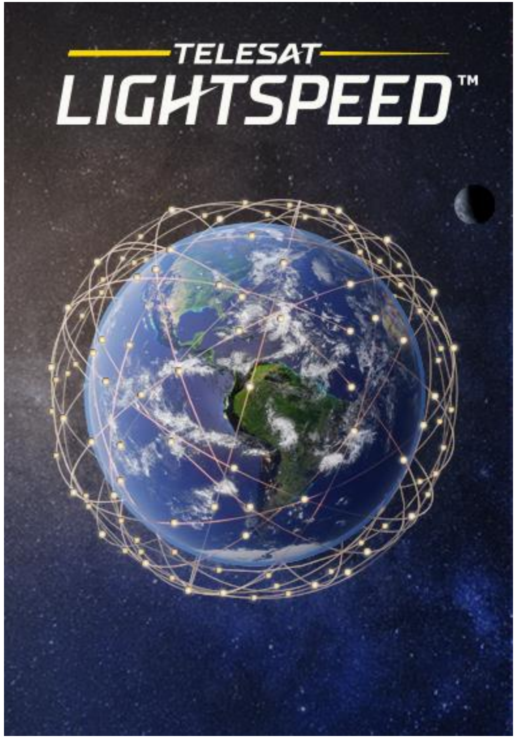
Technology Readiness

- Standard compliant generation of DVB-S2X and RCS2 signals with R&S®SMW200A
- Analysis and reception test of DVB-S2X and RCS2 signals with R&S®FSW
- Used by renown customers all around the world
- Ready for your development and production

Photo: Copyright© Rohde & Schwarz

Technology Readiness

- Telesat Lightspeed is a network of 198 advanced LEO satellites and integrated terrestrial infrastructure that will offer high-speed, low-latency broadband connectivity globally
- Operational in 2027
- The constellation will provide standards-based interfaces to facilitate the use of a variety of user terminal solutions using DVB-S2X and DVB-RCS2 waveforms



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Conclusion

- The DVB set of standards for satellite are mature and actively maintained
- The waveforms are robust and tested by time and application
- The standard has been modernised to the latest NGSO & broadband requirements
- DVB-RCS2/S2X GNSS not required for system synchronisation
- DVB-RCS2/S2X is robust to Doppler due to xPSK waveform and in the case of S2X, pilots.
- System simulations show large gains in link efficiency when using S2X vs RCS2 in the return link.
- System simulations show the combination of RCS2 and S2X on the return link provide competitive performance with respect to NR-PUSCH

Takeaways

- The technology readiness level of DVB-RCS2/S2x is very high with available products and adoption by operators, IC manufactures and OEMs.
- Furthermore, DVB and 3GPP can interface – for example using N3IWF.
  - See ESA / CSC / INN3SCO (INtegration of Non-3GPP Satellite networks with 5G COre networks)

DVB physical layer & 3GPP core network architecture together
can provide the best of both worlds

N3IWF – Non 3GPP Inter-Working Function

Thank You

Technology Readiness

EASii IC's
EziD211 (Oxford-2)
Satellite Modem
ASIC

**Enabling
Broadband Data
via Satellite**

FIXED DATA

Consumer
Broadband
Entreprise
VSAT

INFRASTRUCTURE

Point to point
Telecom
Cellular backhaul
Trunking IP
Earth observation

IOT & M2M

Monitoring &
Metering
Agriculture
Tracking
containers

MOBILITY

Maritime
Aviation
Cars
Trucks

In full mass production

Eu SME

Eu wafer fab & design

ITAR free