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Wish List for the EO Receive Chain

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About Orbital Research

We design and manufacture high-performance frequency converters:

- Ground
- Airborne
- Space

OrbitalResearch.net

Agenda

System overview

Important factors

Link budgets

Trade-offs

What’s your wish list?

System Overview

LEO satellite

Mission data

Ground receive station

Data processing

Data consumption

Low Earth Orbit Satellite

Smallsat

Microsat

Picosat

Big

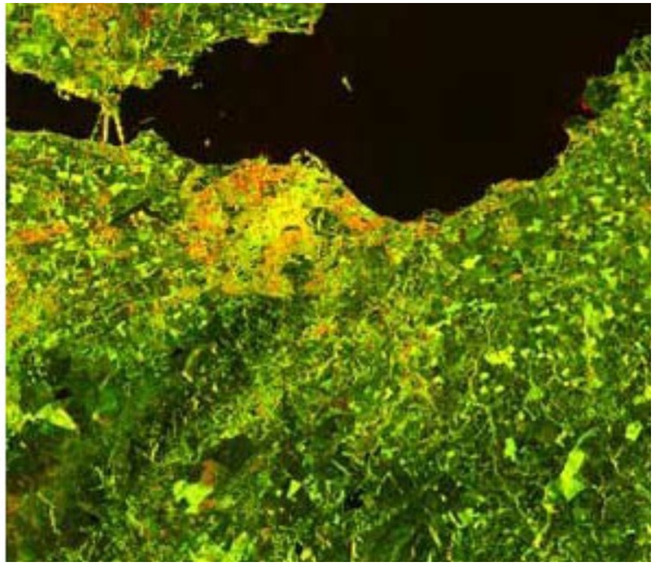
- Mission requirements
- Budget requirements

Mission Data

Data volumes required

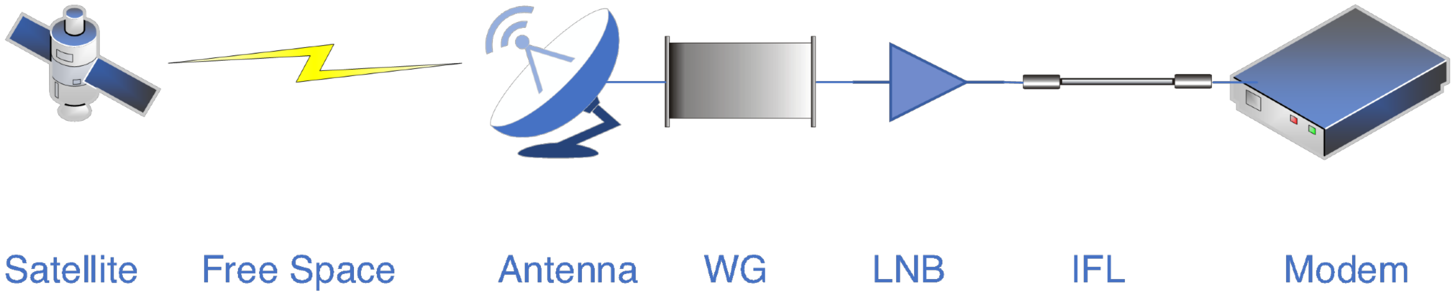
Time sensitivity

Security



Ground Receive Station

- Dedicated earth terminal
- Shared-use terminal
- Terminal performance based on link budget
- Digital IF at antenna
- Fibre optics

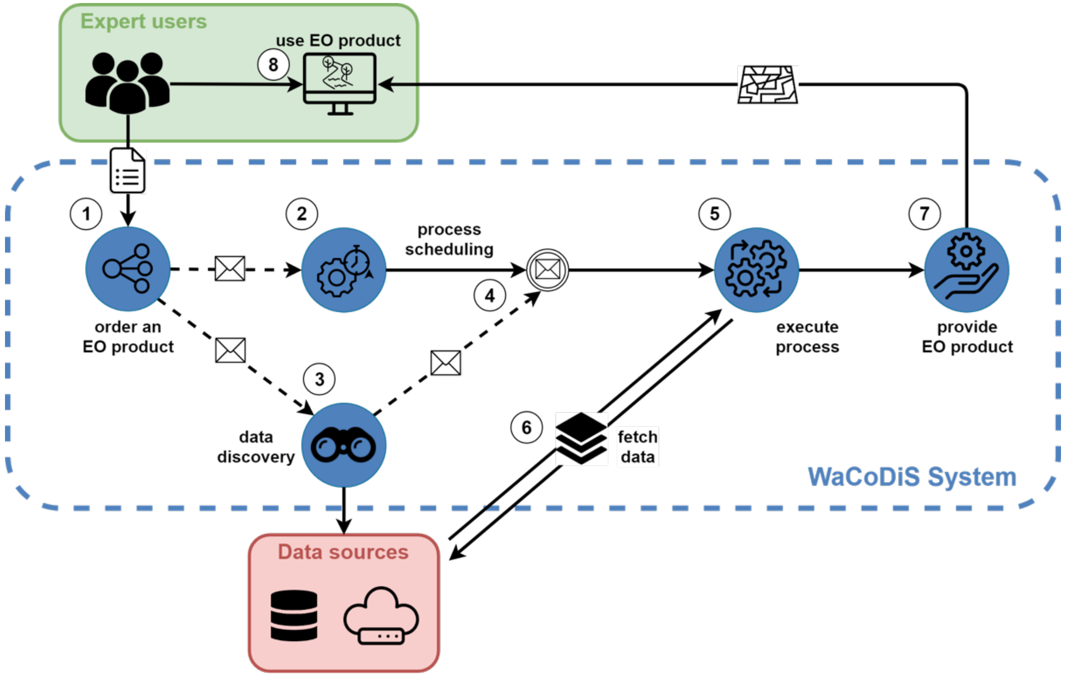


Data Processing

Security

Volume

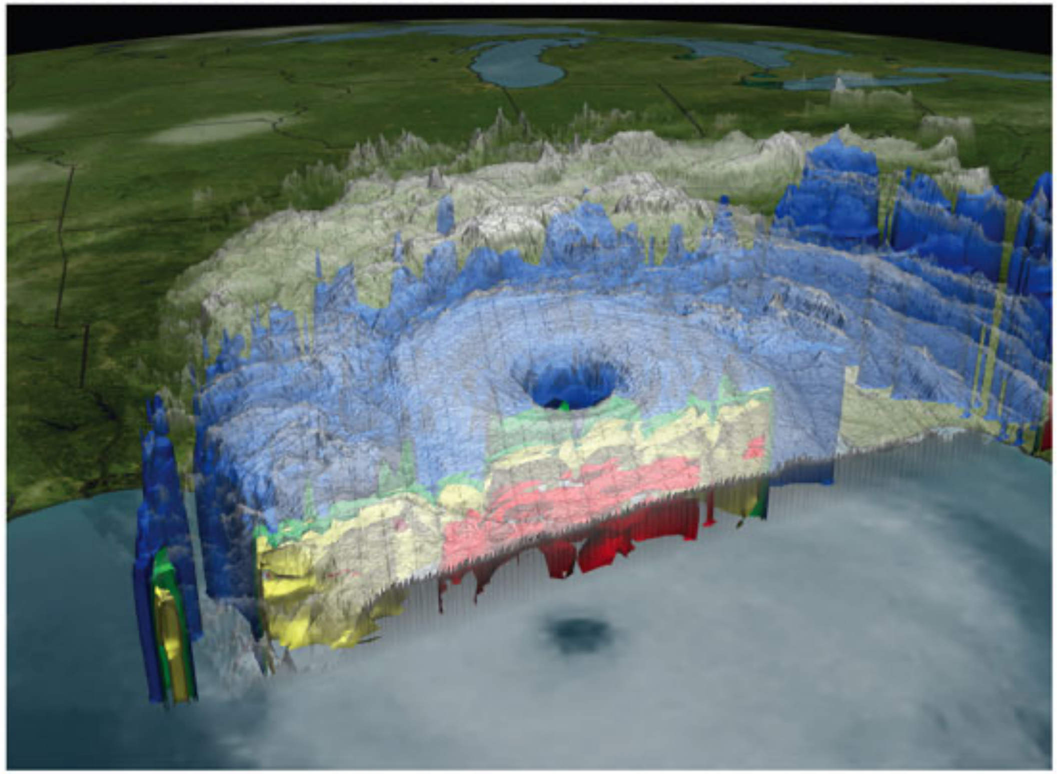
Where can it be processed



Data Consumption

Where is the customer?

How will data be delivered?



Important Factors

They are all important:

- Throughput required -> Satellite design, ground terminal, constellation architecture
- Time sensitivity -> Constellation architecture, ground terminal network
- Cost

Throughput

How much data can be downloaded in a 10 Min Pass?

• 9.6 Kbps = 700 KB	0 dB
• 1 Mbps = 71 MB	20 dB
• 100 Mbps = 7 GB	40 dB
• 1 Gbps = 70 GB	50 dB
• 10 Gbps = 698 GB	60 dB

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The Link Budget

Small Sat

- EIRP 1 dBW
- 1 Mbps
- 25 cm ground antenna
- 500 km orbit

Downlink Calculation	**Clear**	**Rain**	**Units**
Satellite EIRP per carrier	1.00	1.00	dBW
Antenna mispoint	1.00	1.00	dB
Free space loss	163.93	163.93	dB
Atmospheric absorption	0.10	0.11	dB
Tropospheric scintillation	0.00	0.15	dB
Cloud attenuation	0.00	0.09	dB
Rain attenuation	0.00	0.09	dB
Total attenuation (gas-rain-cloud-scintillation)	0.10	0.35	dB
Other path losses	1.00	1.00	dB
Noise increase due to precipitation	0.00	0.34	dB
Downlink degradation (DND)	0.00	0.59	dB
Total system noise	124.26	134.48	K
Figure of merit (G/T)	2.87	2.53	dB/K
Power flux density	-125.97	-126.56	dBW/m2
Carrier power at LNB output	-81.11	-81.70	dBW
Carrier level at LNB output (50 Ohm)	55.88	55.29	dBuV
Carrier level at LNB output (50 Ohm)	-4.12	-4.71	dBmV
C/No (thermal)	66.45	65.85	dB.Hz
C/N (thermal)	6.19	5.59	dB
C/ACI	30.00	30.00	dB
C/ASI	30.00	30.00	dB
C/CCI	30.00	30.00	dB
C/IM	60.00	60.00	dB
C/(N+I)	6.13	5.55	dB
Implementation loss	1.00	1.00	dB
System margin	2.00	2.00	dB
Net Es/(No+Io)	3.13	2.55	dB
Required Es/(No+Io)	1.00	1.00	dB
Excess margin	**2.13**	**1.55**	**dB**

The Need For Speed And Bandwidth

	Bandwidth Required (MHz)			
Bit Rate (Mbps)	QPSK R1/2	8APSK R3/4	64APSK R4/5	256APSK R32/45
1.0	1.2	.5	.35	.18
1,000.0	1,204	483	215	182
10,000.0	12,048	4,830	2,159	1,828

More Throughput

- Increase the modulation, reduce the coding to get more bits/Hz

- 5 times bits/Hz requires 20 dB improvement in C/N

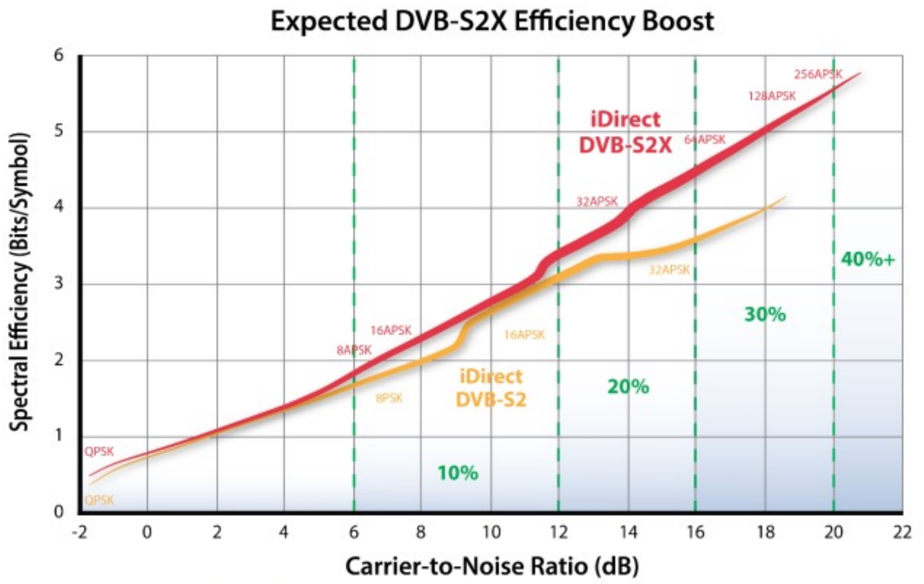
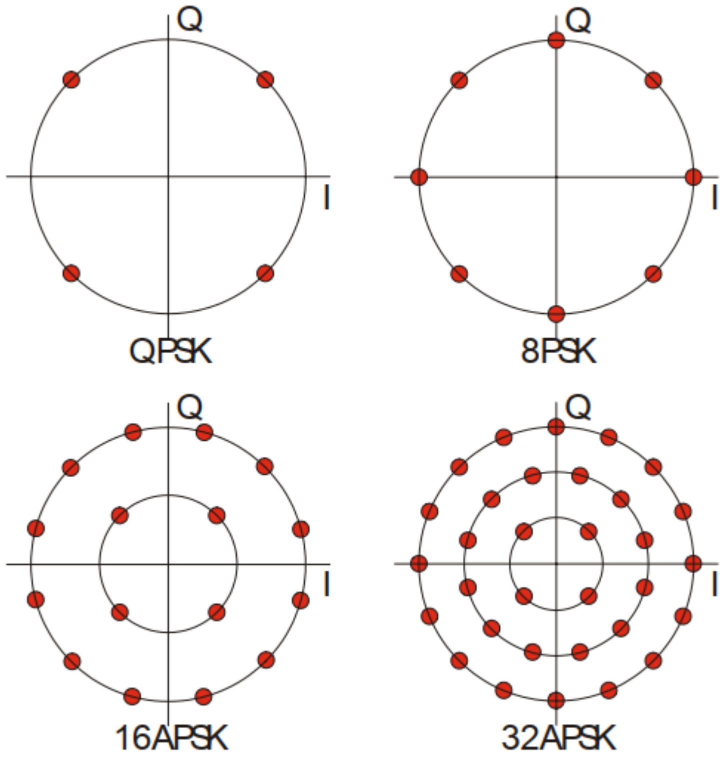


Figure 3: Downstream Efficiency Comparison for DVB-S2X and DVB-S2 modes

Increase Modulation

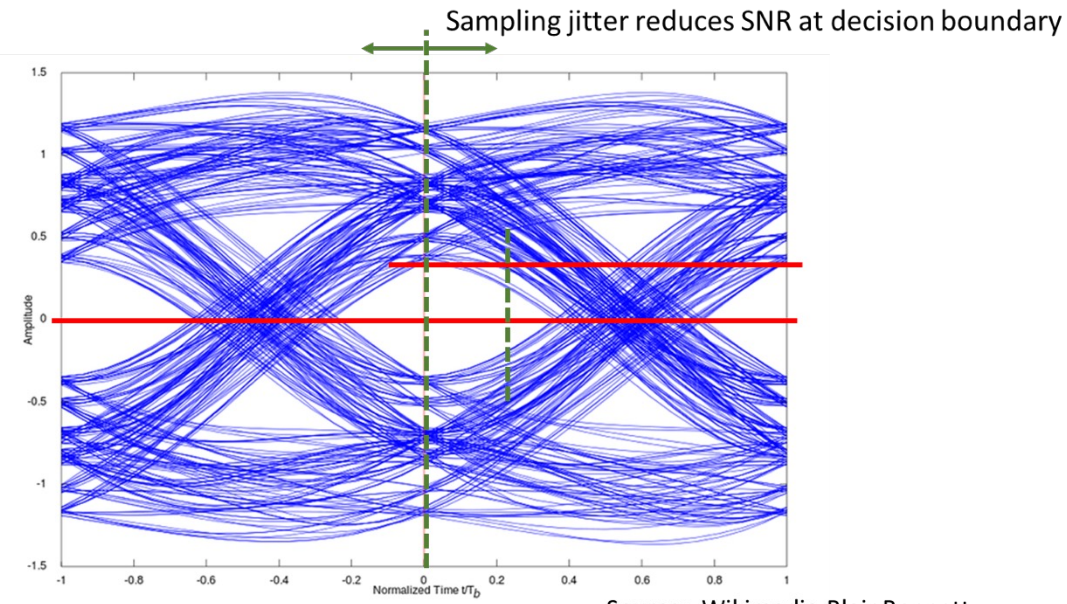
- Complexity of high order modulation can be seen

- Higher order modulation becomes more susceptible to phase noise and system noise



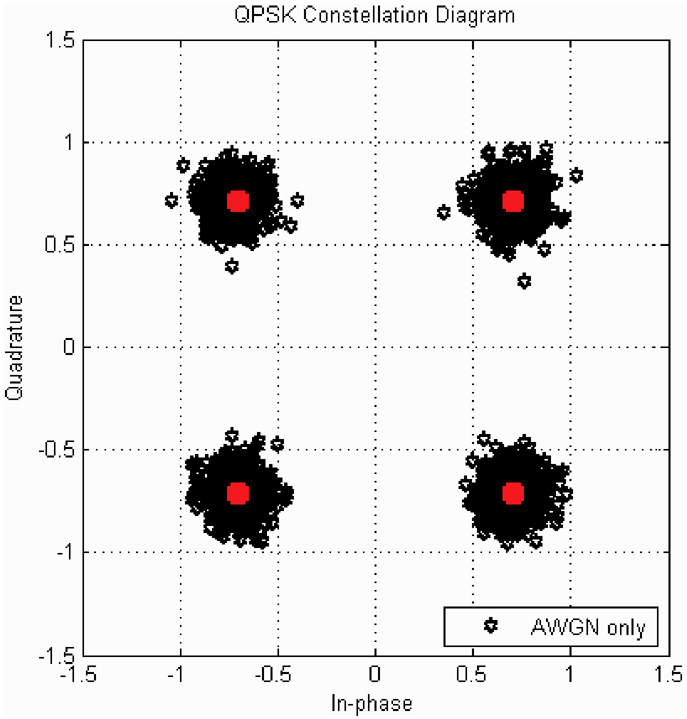
Phase Noise – Eye Diagram

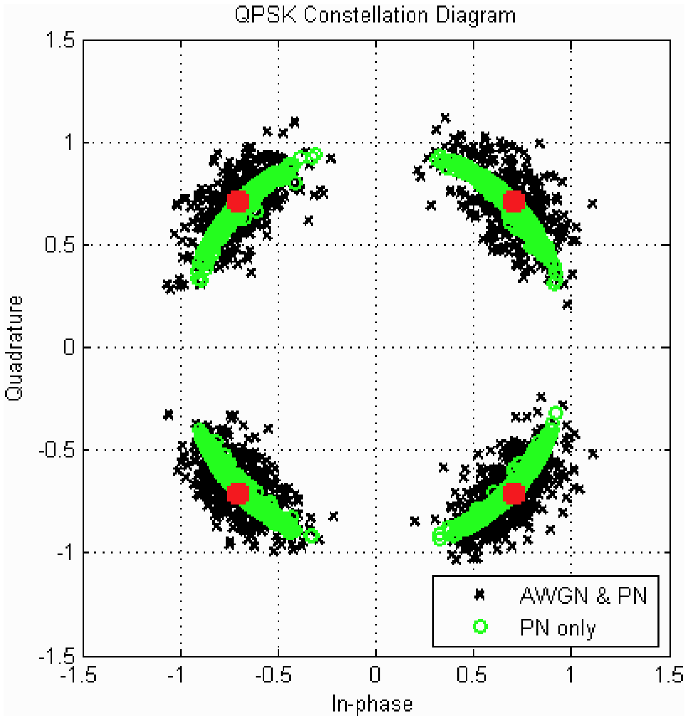
- Phase noise => jitter, which impacts decision point which adds margin requirements to our system



Source: Wikimedia Blair Bonnett

Phase Noise – Constellation Diagram





Phase Noise Impact & Carrier Tradeoffs

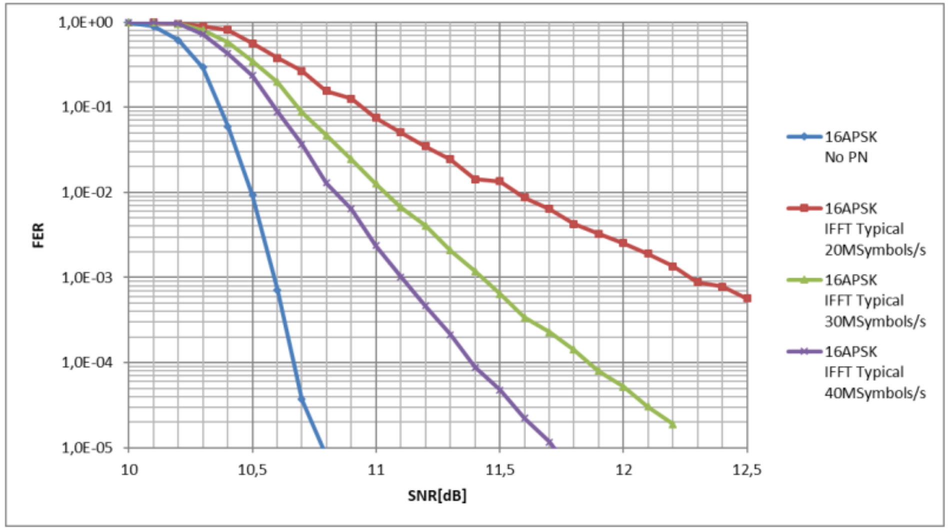


Fig. 14. FER performance for 16-APSK, R_c = 3/4, typical DVB-S2 mask and different symbol rates.

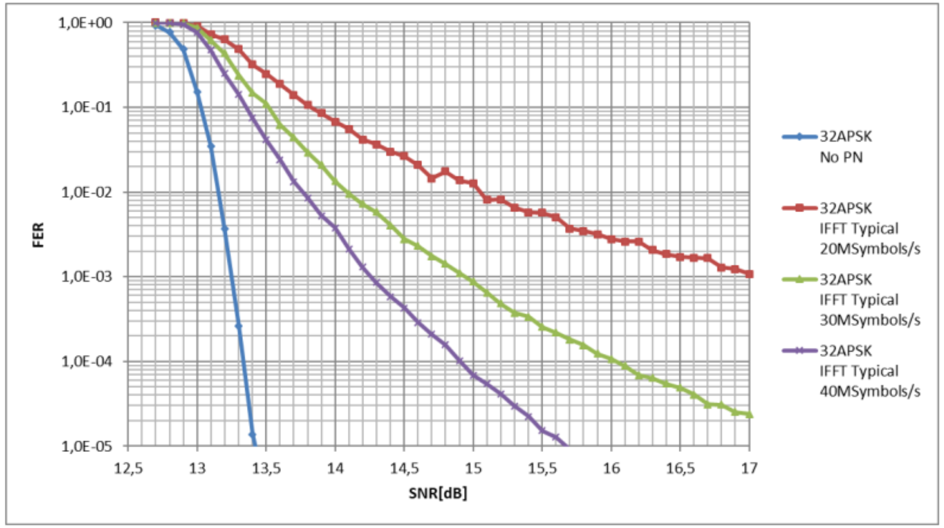


Fig. 15. FER performance for 32-APSK, R_c = 3/4, typical DVB-S2 mask and different symbol rates.

Harald Schlemmer, et al, *Some Notes on Phase Noise Generation and the Impact on DVB-S2x Waveforms,* 2019 15th International Conference on Telecommunications (ConTEL)

Amplifier Linearity

- In bent pipe sat links linearity of the satellite amplifier (TWTA or SSPA) impacts the links
- In EO applications when going to higher order MODCODs it will be an issue for both the satellite amplifier and the GT LNA/LNB
- Path loss difference at overhead vs AOS ~ 15 dB at X Band

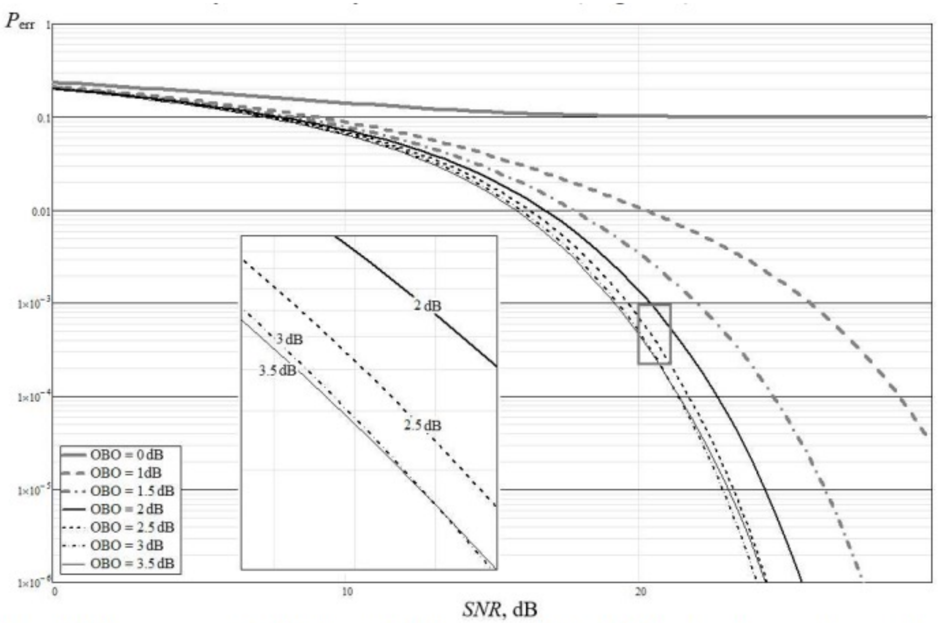


Fig. 10. The error probabilities of APC exposed 16-APSK signals reception with different *OBO* values.

Stanislav S. Degtyarev1, Vladimir I. Nosov, *Research of the Amplitude-phase Conversion Impact on the 16-APSK Signal Noise Immunity*, 2016 13th International Scientific-Technical Conference APEIE

What does it all mean

High throughput requirement means you need:

- More EIRP from Satellite and/or bigger ground terminal
- Better phase noise in your LNB
- Better linearity in your whole receive chain

Trade Offs

- Inter-satellite links to download data through more ground stations
- Store and downlink to multiple smaller ground stations per orbit
- Digital IF or traditional demodulation
- Frequency bands: V/U, L, S, X or K

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Links

https://isotropic.network/wp-content/uploads/2022/01/Link_Budget_Analysis_Guide_v4.1.3_T0001089_RevA_05_02_19-1.pdf

https://public.ccsds.org/Pubs/131x31o1c1.pdf

What’s on your wish list?