Space telecommunications and signal processing

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Dr habil sc ing

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NetWorld2020 full member (Heidelberg)

RTU, 2020, 2.okt.

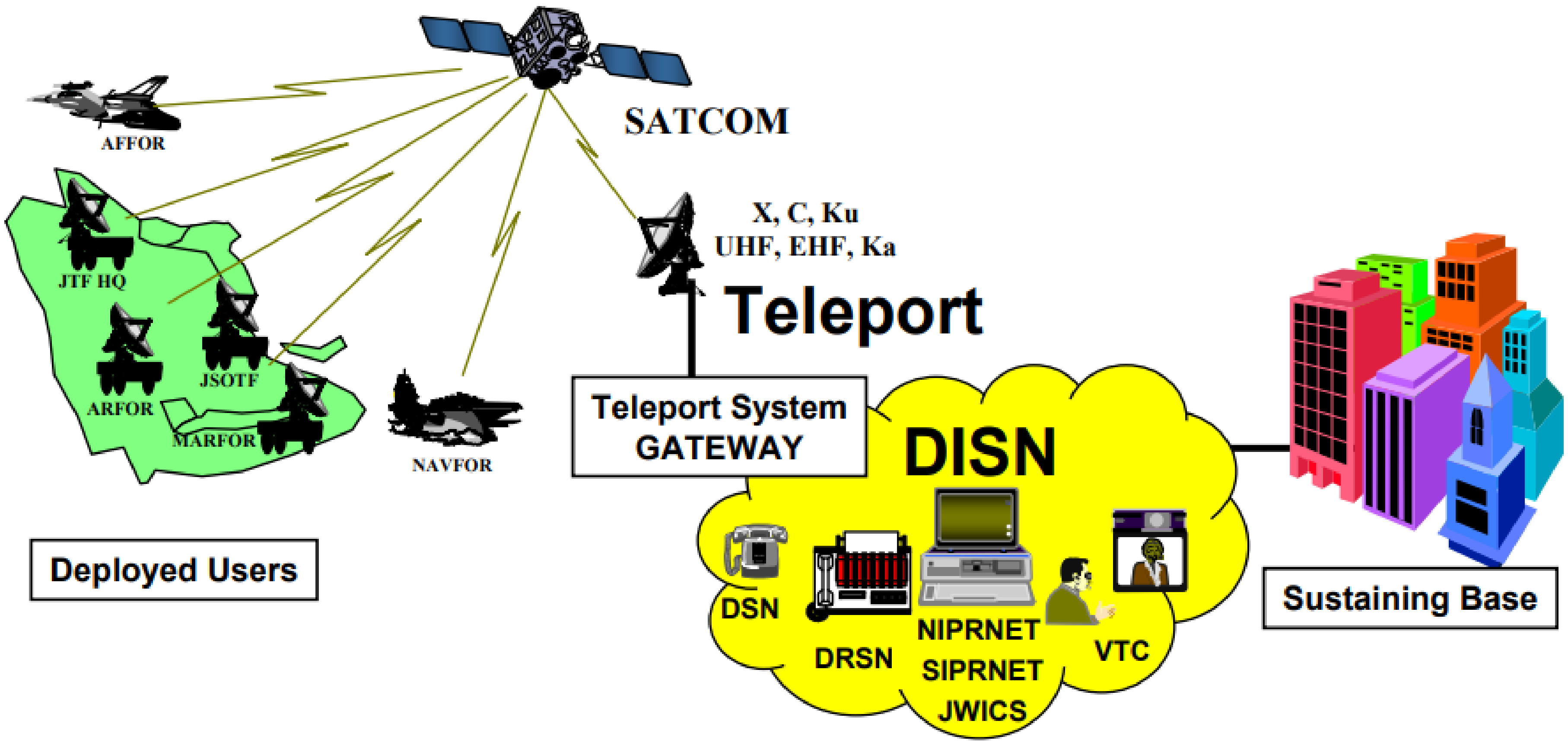
The key goal - the re-equipment of radio telescopes RT-16 and RT-32 for space communications

RT-16

RT-32

•**S Band 2.025 - 2.3 GHz** Space operations and research, including 'deep space' links from beyond Earth orbit.
Unified S-band plan is used by many spacecraft, and was also used by the Apollo lunar missions.
Many Earth resources (remote sensing) satellites downlink in this band.

Teleport "In Context" of U.S. Defense Information Systems Network



DOD Teleport sites are globally-distributed SATCOM facilities. The system has six core Teleport facilities located in Virginia, Germany, Italy, Japan, Hawaii, and California, and three secondary facilities located in Bahrain, Australia (future), and Guam.

RADIO FREQUENCIES FOR SPACE COMMUNICATION

C Band
3.4 - 4.2 GHz Fixed satellite service (FSS) and broadcast satellite service (BSS) downlinks. International TV broadcast uses this allocation heavily.
5.9 - 6.4 GHz This is the FSS/BSS uplink for the 3.4-4.2 GHz downlink band.

X band
8 - 9 GHz This is used heavily for space research, deep space operations, environmental and military communication satellites. Many satellites/spacecraft carry complementary **S and X band transmitters**.

Ku band
10.7 - 11.7 GHz Fixed satellite services (FSS)
11.7 - 12.2 GHz Broadcast satellite service (BSS) downlinks. This band is used for domestic TV programs.
14.5 - 14.8 GHz The uplink for the previous Ku downlink band.

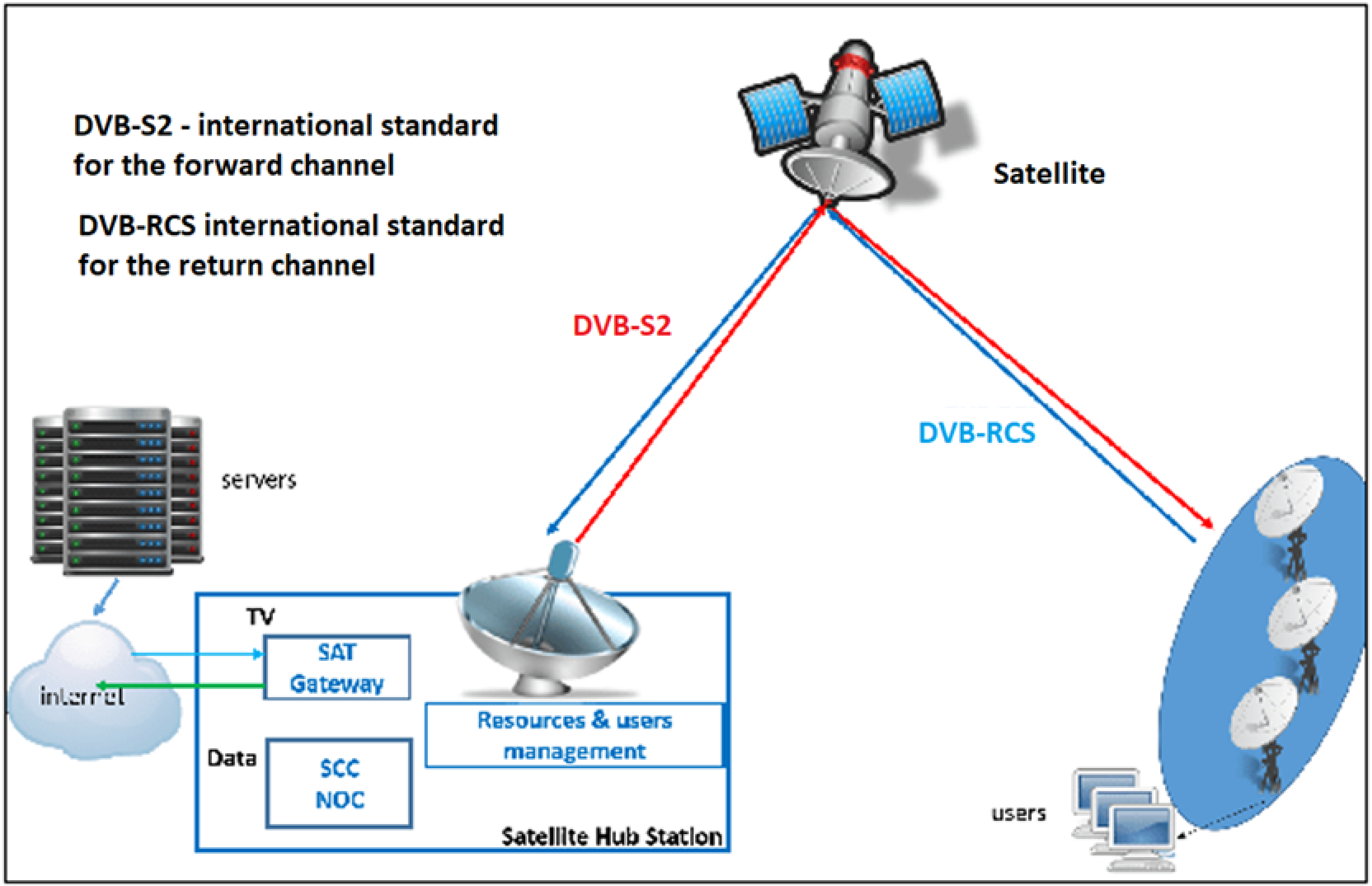
Ka band
23 - 27 GHz A region that will be used increasingly by a variety of fixed link, broadcast, environmental and space operations satellites in the future as more bandwidth is required than can be provided in the lower bands. The disadvantage of this band is the increased absorption due to water vapour and rain. Not very useful for tropical regions of the Earth.

Presentation outline

1. Satellite communications
2. Nanosatellites
3. Signal processing (tutorial MatLab based)
4. VIRAC perspectives:

- NetWorld2020 - European Technology Platform
- European Space Agency: Satellite Communications

1. Satellite communications schema



DVB-S2 features

A flexible input stream adapter, suitable for operation with single and multiple input streams of various formats (**packetized or continuous**);

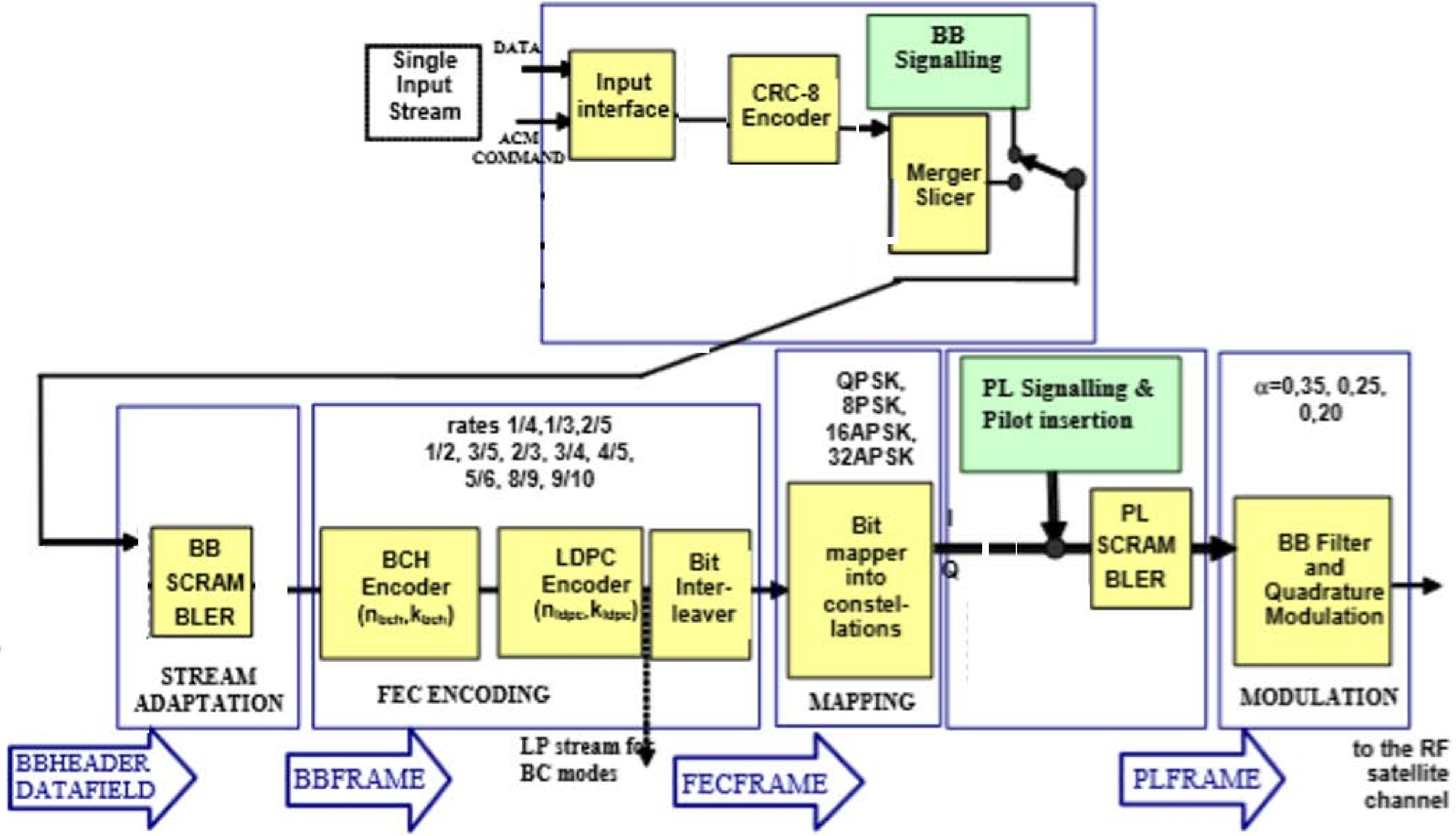
A powerful FEC (Forward Error Correction) system based on **LDPC (Low-Density Parity Check) codes** concatenated with BCH (Bose-Chaudhuri-Hocquenghem) codes, allowing Quasi-Error-Free operation at about 0,7 dB to 1 dB from the Shannon limit;

A wide range of **code rates (from 1/4 up to 9/10); 4 constellations**, ranging in spectrum efficiency from 2 bit/s/Hz to 5 bit/s/Hz;

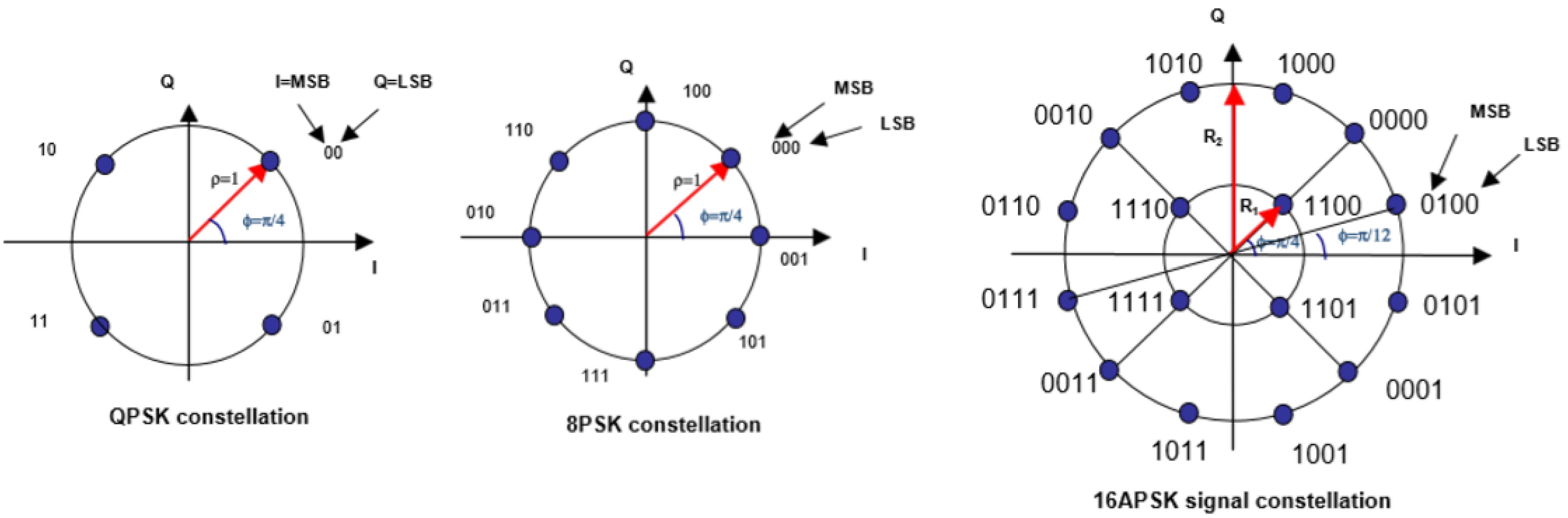
A set of three spectrum shapes with **roll-off factors 0,35, 0,25 and 0,20**;

Adaptive Coding and Modulation (ACM) functionality, optimizing channel coding and modulation on a frame-by-frame basis.

Functional block diagram of the DVB-S2 System (single stream)

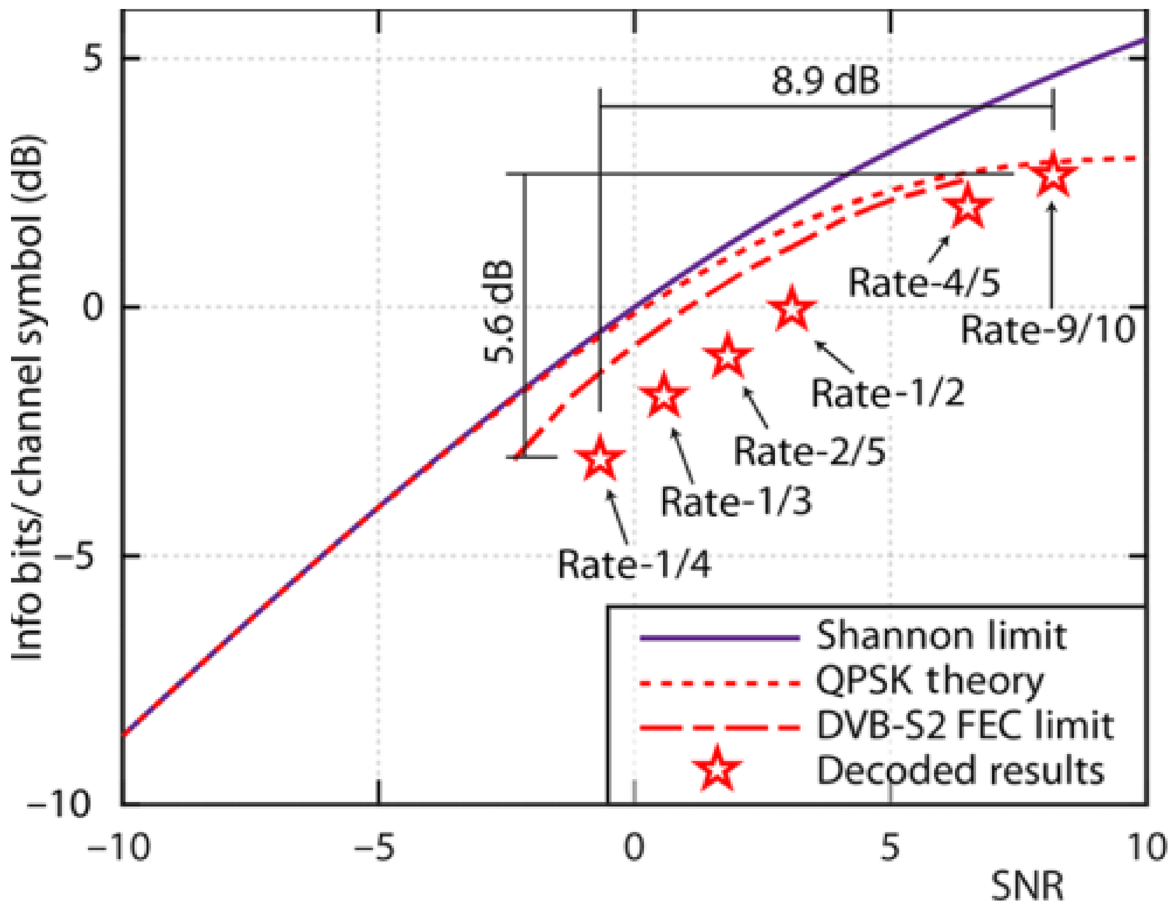


Bit mapping into signal constellation

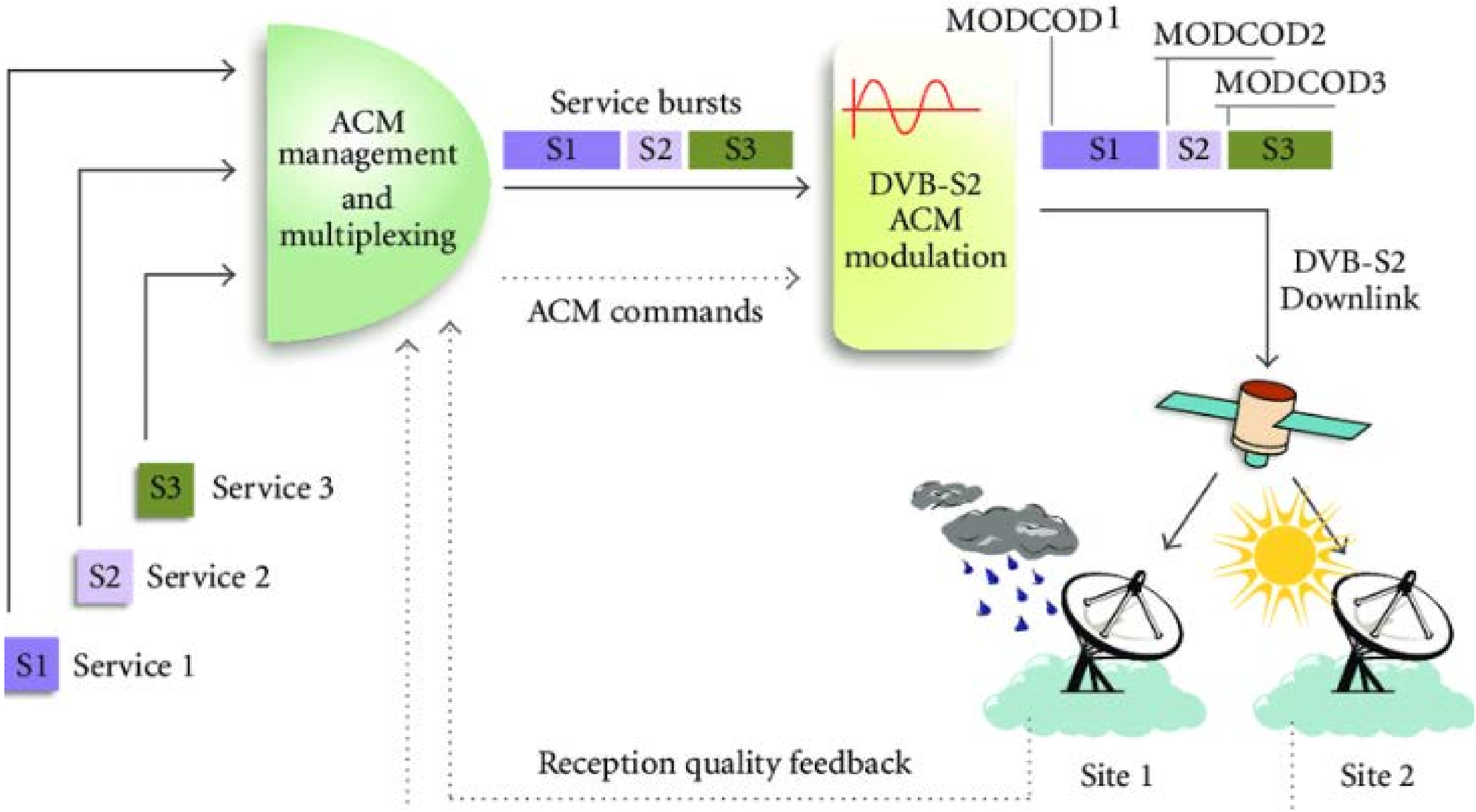


Each FECFRAME (which is a sequence of 64 800 bits for normal FECFRAME, or 16 200 bits for short FECFRAME), shall be serial-to-parallel converted (2 for QPSK, 3 for 8PSK, 4 for 16APSK, 5 for 32APSK)

Shannon limit and DVB-S2 decoded results



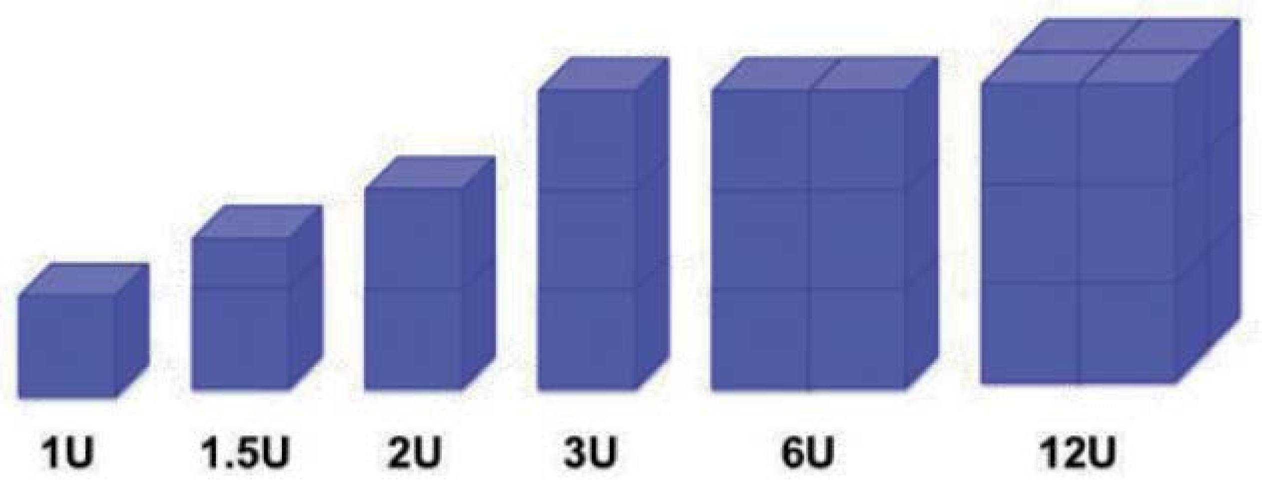
DVB-S2 adaptive coding and modulation



2. Satellite classification

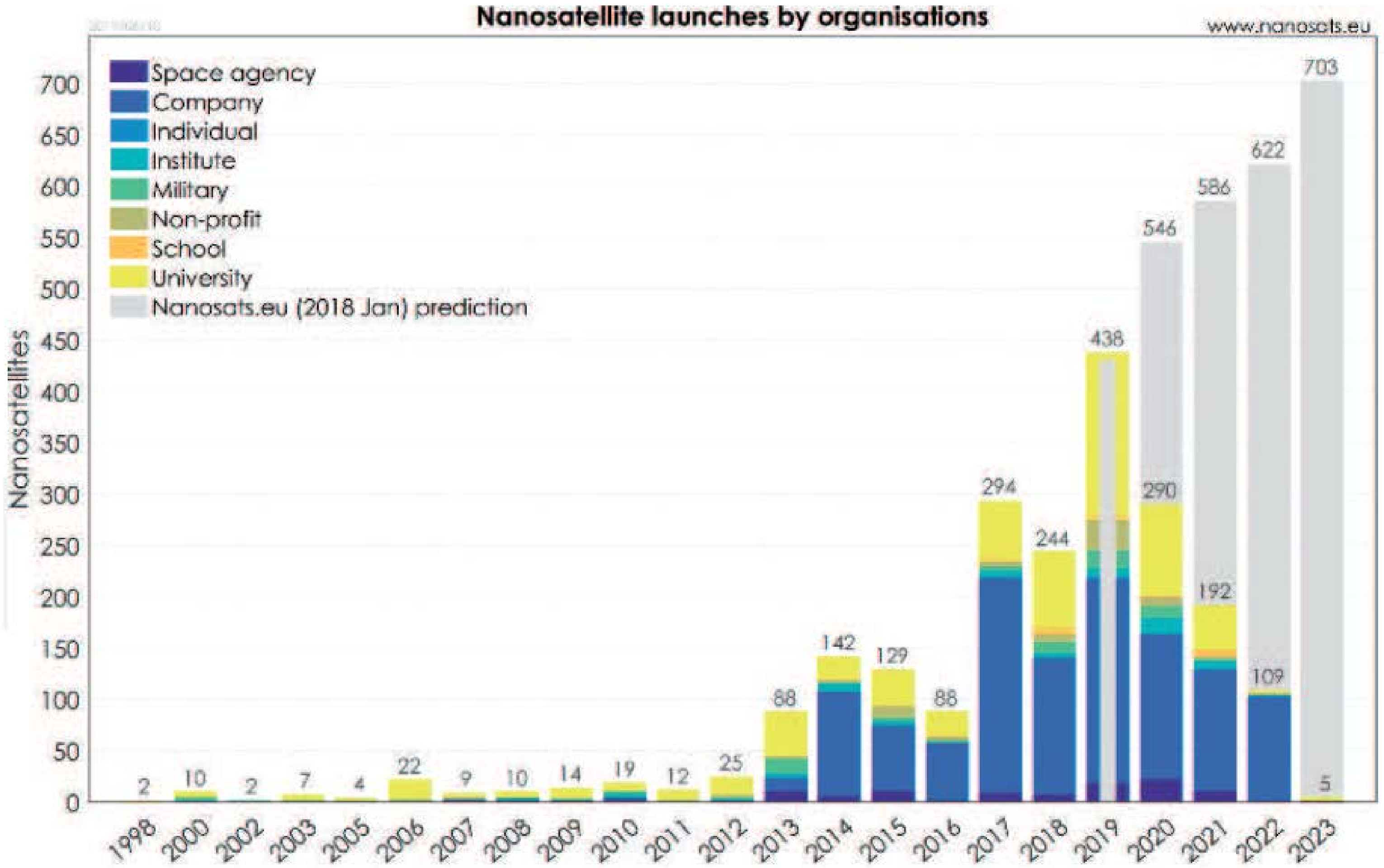
Nanosatellites: CubeSat standard

CubeSats are small satellite multiples of 1 U
(1 U: 10 cm × 10 cm × 11.35 cm, weighing less than 1.33 kg), including all the basic subsystems as large satellites but using COTS components.



CubeSat form factors from 1 U to 12 U

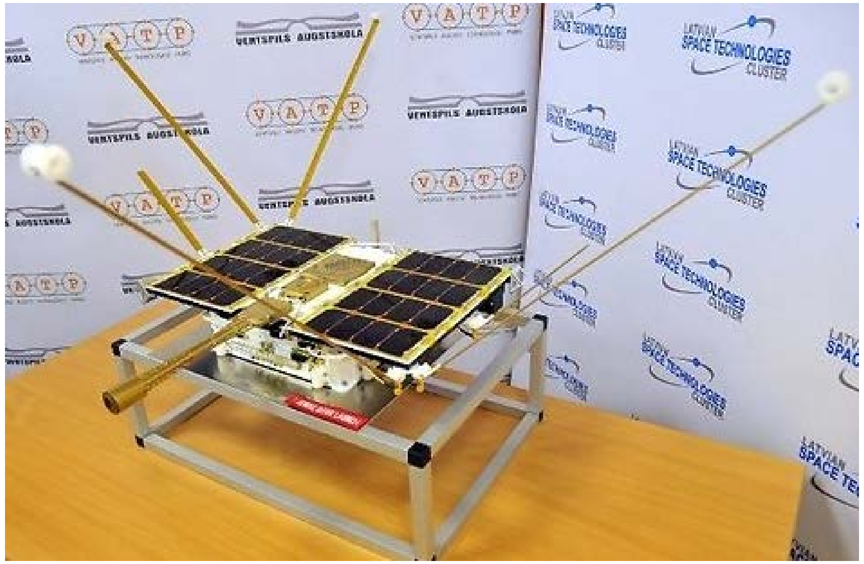
The number of nanosatellites launched per year



Nanosatellites and Applications to Commercial and Scientific Missions
DOI: http://dx.doi.org/10.5772/intechopen.90039

Venta-1

Venta-1 is Latvia's first artificial satellite to be launched into polar orbit on June 23, 2017. It is intended for testing of Automatic Traffic Identification Systems (AIS), communications between satellites and imaging cameras. The project was led by Ventspils University College, involving the German company OHB-System AG, Bremen University College and Ventspils High Technology Park.



Venta-1 presentation 31 aug 2011.

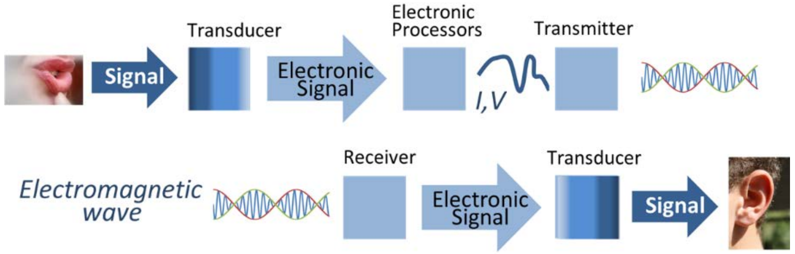
Dutch space company Hiber orbital constellation of CubeSats

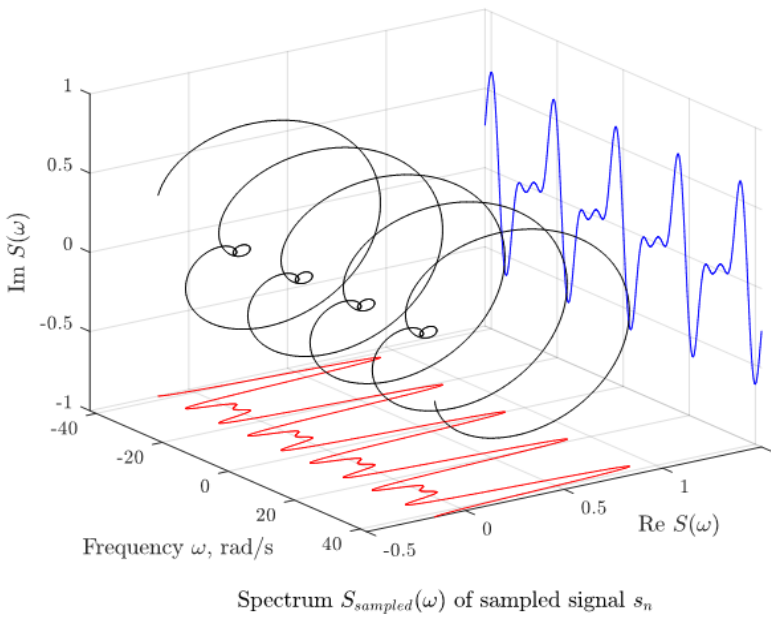
Dutch space-based Internet of Things (IoT) startup Hiber is building an orbital constellation of CubeSats to provide global low-cost connectivity for the ‘Internet of Things’. Hiber received an undisclosed share of a €278 million European Innovation Council Accelerator grant as well as direct equity investment. Founded in 2016, Hiber employs over 50 individuals and aims to build and launch a IoT constellation of 48 satellites.

Hot data from the coldest Pole

The ice cap is shrinking. Fortunately, the data we need to stop this is increasing. Time to tackle climate change.

3. Signal processing theory (tutorial MatLab based)





spectral representation

sampled signals, complex signals,

information transmission using orthogonal sine waves,

modulations,

spectrum modifications

(like Direct Sequence Spread Spectrum, etc.)

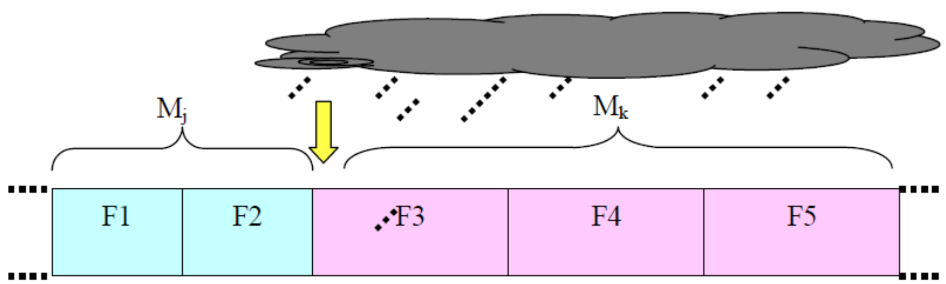
See: papers by E. Tikhonov and M. Sneps-Sneppe

In “International Journal of Open Information Technologies”

vol. 7, no.3, no.4, and no.7, 2019; vol. 8, no.6, 2020

Statistical satellite signal processing (tutorial)

Adaptive Coding and Modulation (ACM) functionality, optimizing channel coding and modulation on a frame-by-frame basis



PLFRAMEs changing protection during a rain fading

Example - Phase Estimation

Assume that we wish to estimate the phase ϕ of a sinusoid

$$x[n] = A\cos(2\pi f_0 n + \phi) + w[n] \qquad n = 0, 1, \ldots, N-1.$$

The amplitude A and frequency f_0 are assumed known. The PDF is

$$p(\mathbf{x};\phi) = \frac{1}{(2\pi\sigma^2)^{\frac{N}{2}}} \exp\left\{-\frac{1}{2\sigma^2}\sum_{n=0}^{N-1}[x[n] - A\cos(2\pi f_0 n + \phi)]^2\right\}.$$

Differentiating the log-likelihood function produces

$$\frac{\partial \ln p(\mathbf{x};\phi)}{\partial\phi} = -\frac{1}{\sigma^2}\sum_{n=0}^{N-1}[x[n] - A\cos(2\pi f_0 n + \phi)]A\sin(2\pi f_0 n + \phi)$$

and

$$\frac{\partial^2 \ln p(\mathbf{x};\phi)}{\partial\phi^2} = -\frac{A}{\sigma^2}\sum_{n=0}^{N-1}[x[n]\cos(2\pi f_0 n + \phi) - A\cos(4\pi f_0 n + 2\phi)].$$

Upon taking the negative expected value we have

$$-E\left[\frac{\partial^2 \ln p(\mathbf{x};\phi)}{\partial\phi^2}\right] = \frac{A}{\sigma^2}\sum_{n=0}^{N-1}[A\cos^2(2\pi f_0 n + \phi) - A\cos(4\pi f_0 n + 2\phi)] \approx \frac{NA^2}{2\sigma^2}$$

Therefore,

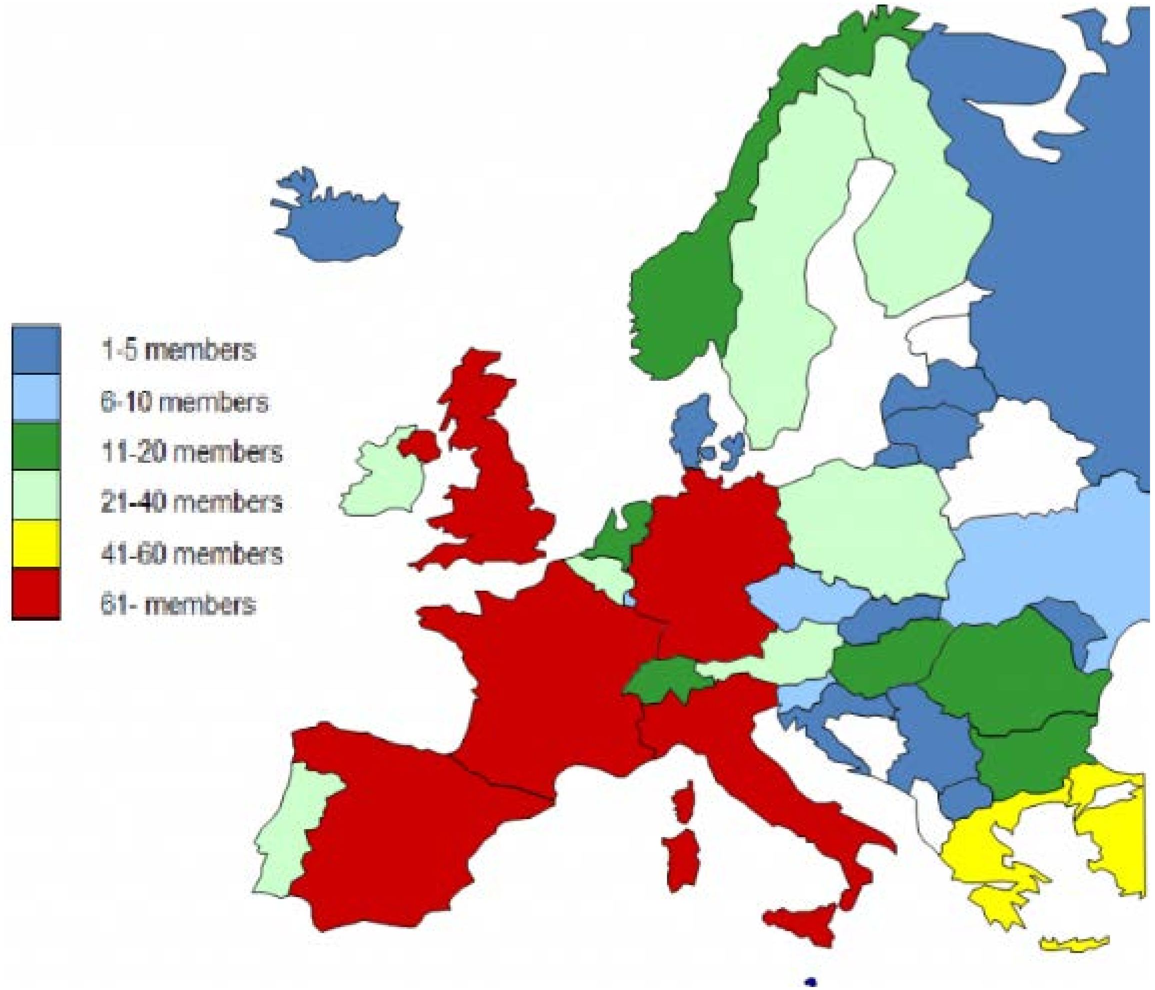
$$\mathrm{var}(\hat{\phi}) \geq \frac{2\sigma^2}{NA^2}.$$

4. VIRAC perspectives: NetWorld2020

NetWorld2020 - European Technology Platform for communications networks and services

The NetWorld2020
Currently 1045 members
(representing 5 % of European GDP)

The head quarter –
EURESCOM (Heidelberg)



Eurescom

Eurescom is a private organisation for managing European research and development projects in telecommunications. Eurescom is based in Heidelberg, Germany, and currently has 16 network operators as members performing collaborative research and development.

Members

- Deutsche Telekom, Germany
- France Telecom, France
- BT Group, United Kingdom
- OTE, Greece
- Portugal Telecom, Portugal
- Telekom Austria, Austria
- Telenor, Norway
- eircom, Ireland
- Magyar Telekom, Hungary
- CYTA, Cyprus
- Síminn, Iceland
- Slovak Telecom, Slovak Republic
- Republic Telecommunication Agency (RATEL), Republic of Serbia
- Swisscom, Switzerland
- Telecom Italia, Italy

Megatrends of Future Networks

(Political, Economic, Social, Technological, Legal and Environmental)

NetWorld2020 Strategic Research and Innovation Agenda 2021-27

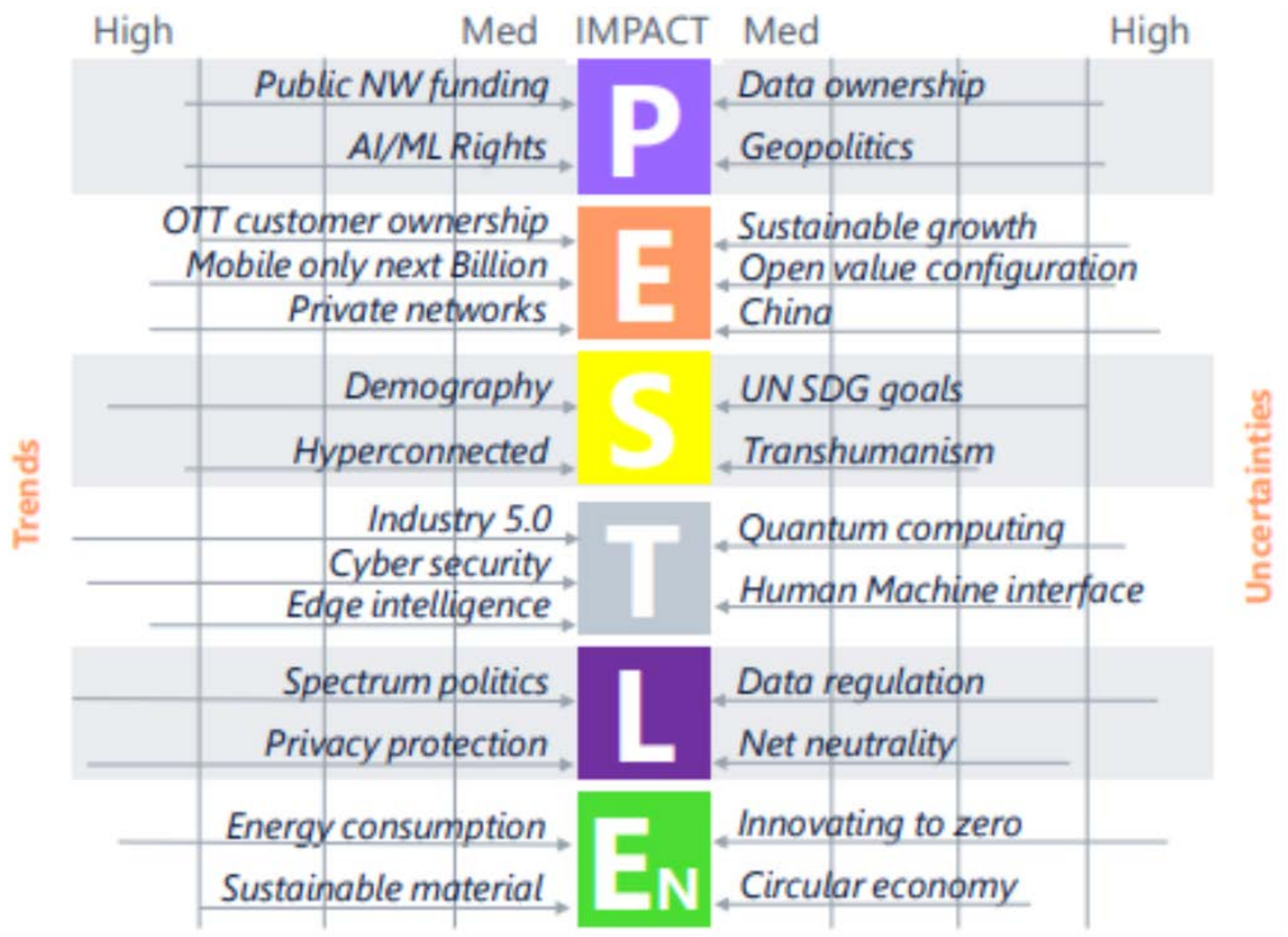
“Smart Networks in the context of Next Generation Internet”

September, 2020

UN Sustainable Development Goals

Examples

- By 2030, double the agricultural productivity and incomes of smallscale food producers.
- Easy connection and management of massive IoT devices.



Fraunhofer Institute for Open Communication Systems (FOKUS)

With 500 employees the **Fraunhofer Institute for Open Communication Systems** (FOKUS) is one of the largest Fraunhofer institutes. FOKUS develops urban IT infrastructures and counsels industry, public administration and organisations in the conceptualisation of complete IT strategies, the selection, engineering and deployment of appropriate solutions as well as the drafting of legislation in the IT context.

The 10 competence centers at FOKUS are designed to cover the complete chain of development of urban IT infrastructures. This enables the digital governance and ensures that critical infrastructures such as traffic, power supply and medical help continue to function reliably and secure, round-the-clock.

VIRAC perspectives: European Space Agency (ESA)

The **Directorate of Telecommunications and Integrated Applications (TIA)** is the most business-oriented part of ESA. This is achieved through **ESA's programme of Advanced Research in Telecommunications Systems (ARTES).**

Three priorities in the 2020-22 programme:

Space for 5G, which aims to integrate satellite telecommunications with terrestrial.

Space Systems for Safety and Security ("4S"), which aims to develop secure satellite communications.

Optical Communications – ScyLight, which aims to develop and demonstrate optical communication technology for satellites.

ESTEC:
ESA's Space Research and Technology Centre

Noordwijk, Netherlands

Thank you for your attention!