UNIVERSIDAD DE MÁLAGA

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SUBJECTIVE QUALITY in UNDERWATER ACOUSTIC NETWORKS

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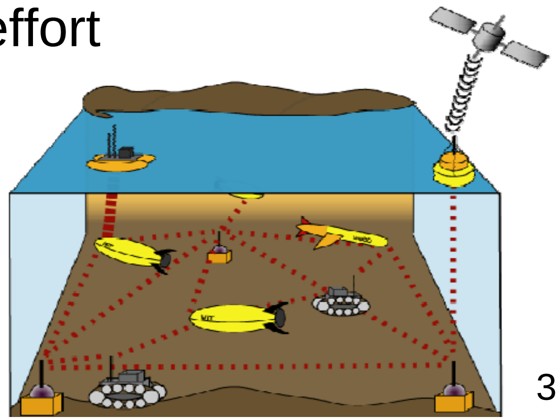
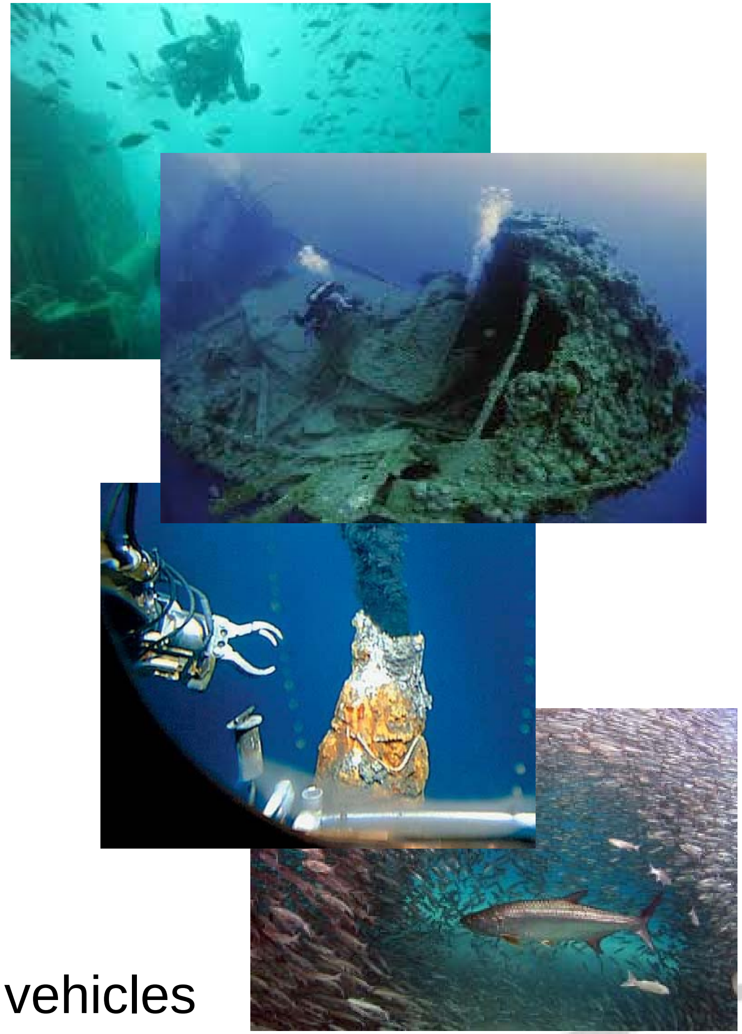
Introduction

- Oceans cover about 70 percent of the Earth’s surface, and much of this vast resource remains to be explored
  - It is possible to chat from the International Space Station and make phone calls from the summit of Mount Everest, so why can't we check our email from the ocean floor?
- The volume below the sea surface has been traditionally ignored
  - It’s a harsh environment that requires advanced technology
  - Resources are much easier to collect on the surface
  - Expansion has been possible without much effort
  - Even now, space resources look more tempting



UAC Applications

- Scientific
  - Submarine life monitoring
  - Natural phenomena forecasting
- Industrial
  - Aquaculture
  - Exploitation of mineral resources
- Environmental
  - Pollution control
  - Climate parameters recording
- Safety
  - Search and rescue missions,
  - Communication between divers and vehicles



Málaga

- Phoenicians, Greeks, Romans, Arabs, …
  - Multicultural city
- Metropolitan Area
  > 700.000 people
- Important Airport & Harbour
- **Coastal City**

Wireless Underwater Waves

- Traditionally, underwater communication is achieved via cables
  - Cables are expensive and heavy-weighted: several tens or hundreds of meters
  - Movement constraints for vehicles and divers
  - Safety issues as cables may pose dangers

→ Wireless underwater communications is a must

Wireless Underwater Waves

- Radio-Electromagnetic waves
  - EM waves do not travel well through thick electrical conductors like salt water
  - Strong absorption + Huge attenuation with distance

⇒ **Only for very short range communications**

- Optical communication

  Blue-green region (450-550 nm)

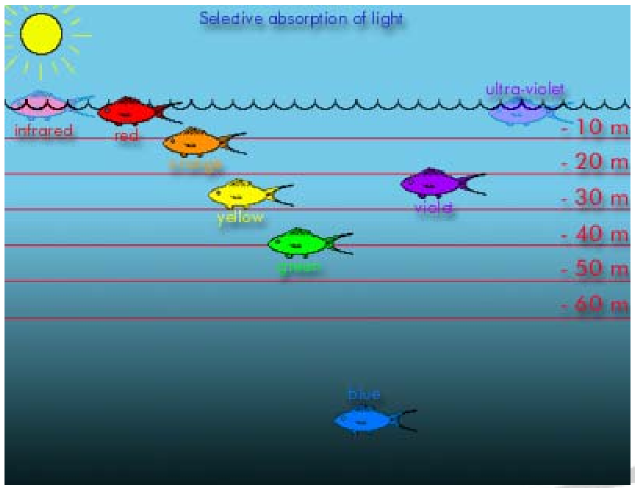
  + High bandwidth (~Mbps)

  + Negligible delay

  – Short distance (<100 m)

  – Alignment of transmitter/receiver

Light Depth Attenuation



Underwater Acoustics

- Used by submarine fauna
- Frequency range: 1 Hz - 500 kHz
  - A 30 kHz frequency (ultrasound) = 6 GHz in air (microwave) (wavelength = 5 cm)
- Negative propagation characteristics
  - Limited bandwidth: 8kHz to 48-78 kHz
  - Time-varying multipath propagation: Reflections from surface, sea floor
  - Low speed of sound underwater: ~1500 m/s

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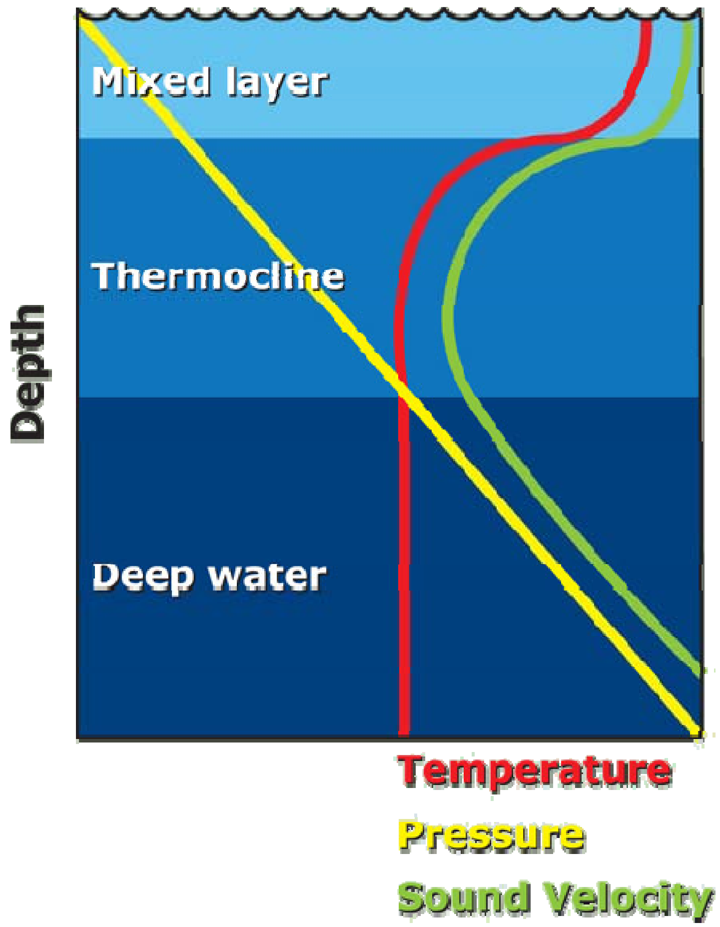
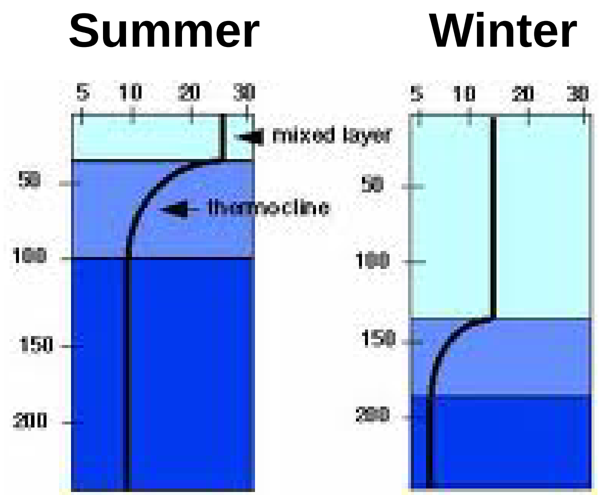
Underwater Acoustic Channel

- The underwater acoustic channel is affected by many factors
  - Salinity
  - Temperature
  - Seabed topology
  - Speed of sound
  - Surface wind-speed
  - …
- This causes multi-paths, reverberation, Doppler, time-varying paths, …
- The result: the communication channel has poor quality and high latency
  - Challenges are very different from terrestrial wireless

Propagation Speed

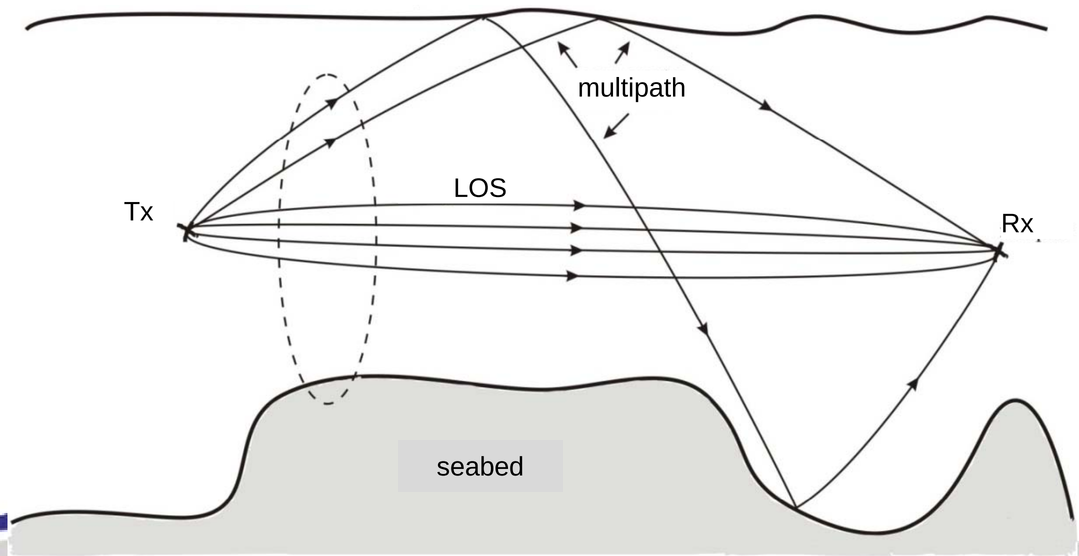


- Typical: 1500 m/s
  Range: 1450m/s – 1540 m/s
- As depth increases, speed decreases
- After 500-600 meters the increasing pressure causes an increase in speed



Scattering

- When the surface of the water is in movement, it causes a dispersal of the delays of the multiple reflections
- Time of coherence decreases
- Experimental measurements show that scattering increases with frequency, distance and wind speed



Bubbles are not So Funny

- Bubbles that appear on the surface may have a big influence on high frequency acoustic signals
- Effect: Increased attenuation of reflected signals

- Bubble density increases with wind speed
  - At 10 m/s, attenuation due to bubbles is up to 20 dB

- Bubbles underwater also create additional scattering

Noise

- Impacts the choice of carrier frequencies
- Natural and human-origin sources of noise:

  waves, turbulences, animals, ships

- Frequency ranges

  Low (< 10 Hz): seismic, storm, turbulences

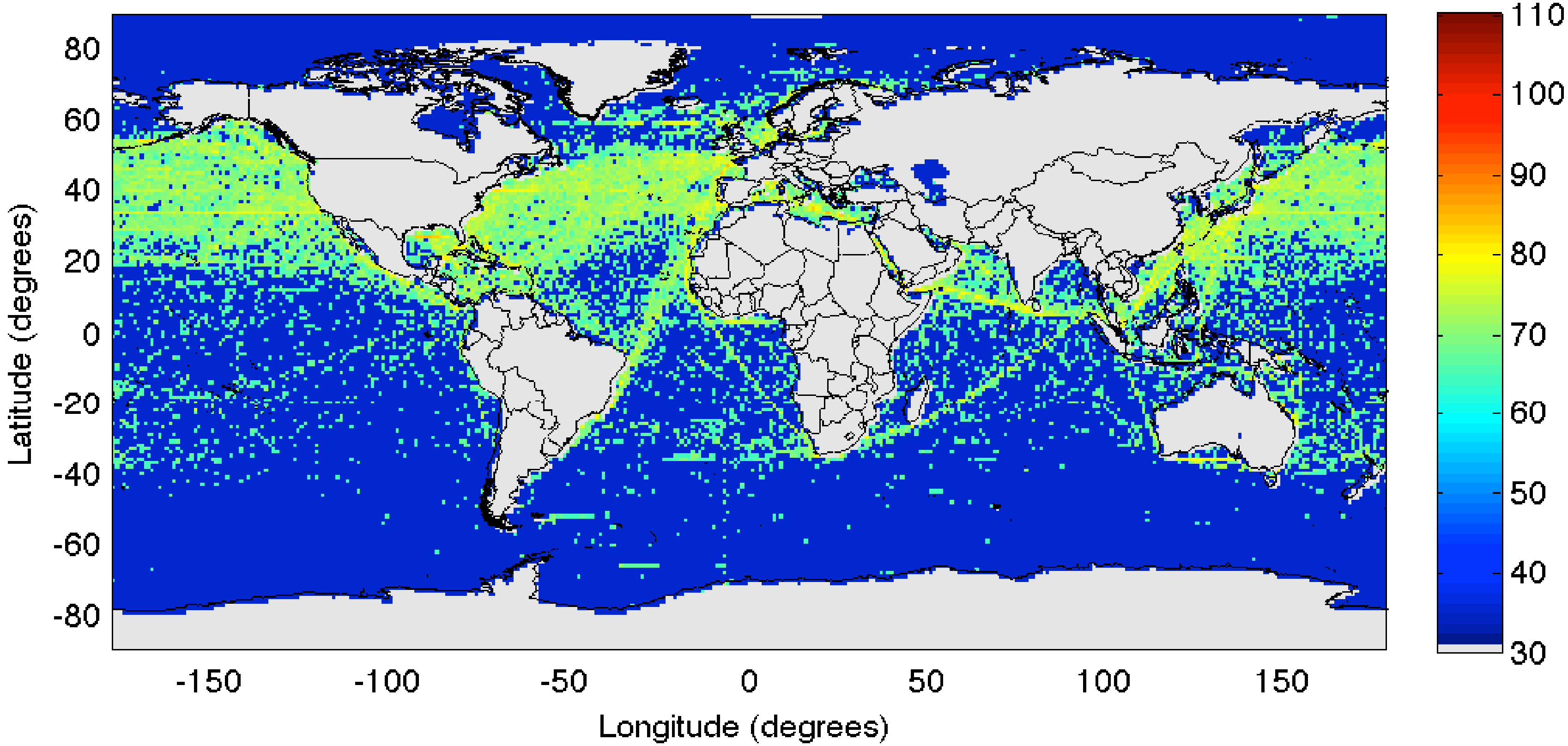
  Medium (50 ~ 300 Hz): ships

  High (> 500 Hz): wind, cavitation, bubbles

- Discontinuous biological noise (in time and space)
- Decreasing power spectral density:

  < 10Hz: 8 ~ 10 dB/octave Above 10 Hz: 5 dB/octave

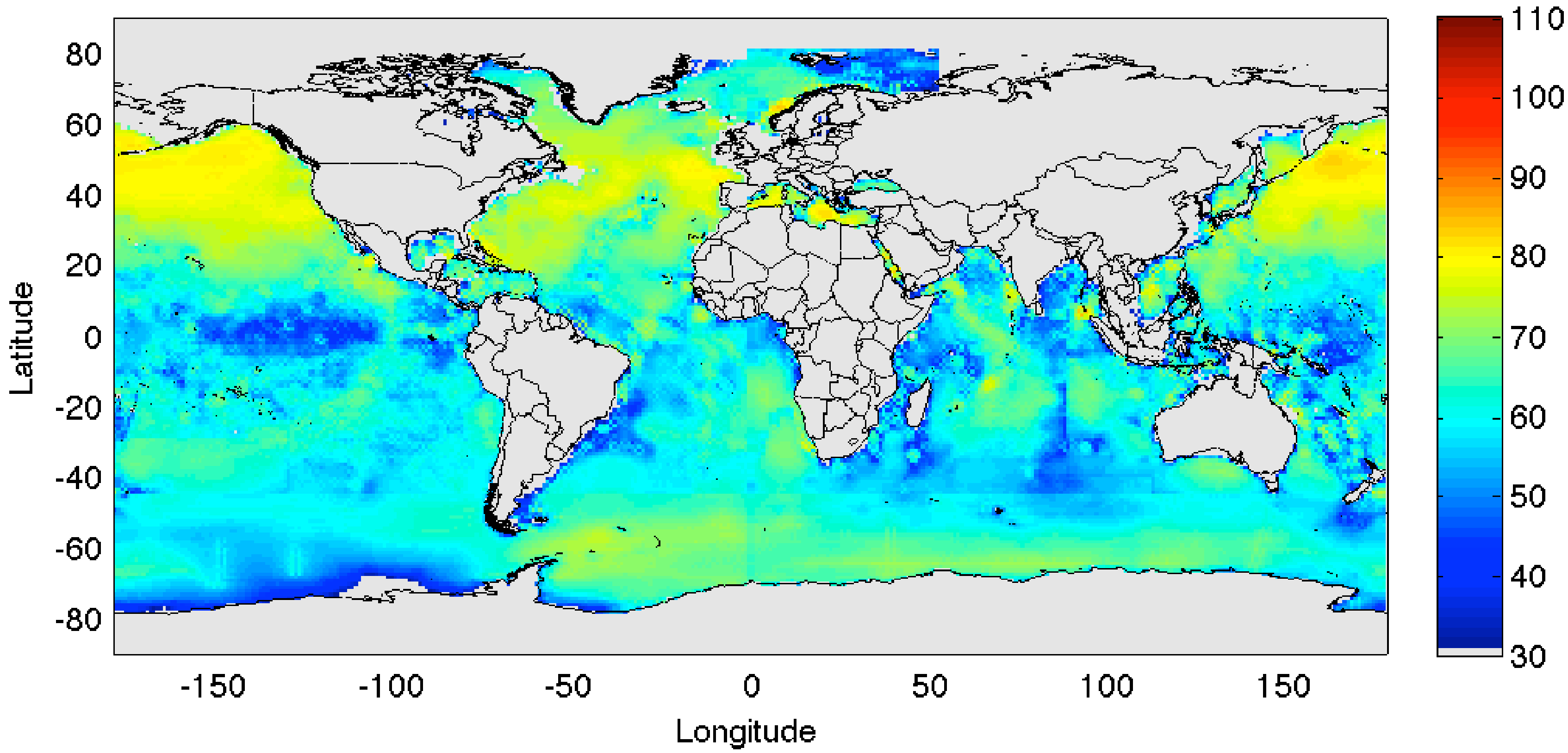
Submarine Environment



Global Shipping Noise at 200 Hz – Points of Origin

[*Ocean Acoustics Library*]

Submarine Environment



Global Shipping Noise at 200 Hz - Aggregate

[*Ocean Acoustics Library*]

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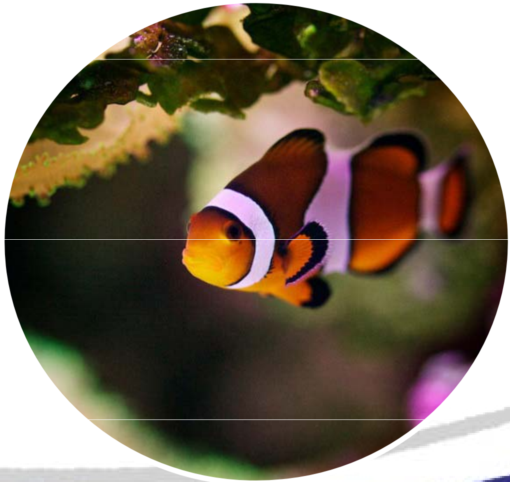
Motivations

- **Ocean scientists** often need not only sensor measures (temperature, salinity…) but also they **need to watch** underwater environments.

- **Images** from oceanic resources are currently **difficult** and **expensive** to obtain.
  - Exploration expeditions with divers or robots submerging with cameras are needed.

- **Video** services **in USNs** would allow to **reduce** these **costs**.



Problems and research targets

- **Main problem** for underwater video services is the **highly limited bitrate** available with current technology.
  - State of the art acoustic modems reach **31,2 kbps** peak data rate at physical layer.

- It is necessary to study if video services are possible and what **QoS** could be achieved in these **low bitrate conditions**.

ITU-T G.1070 model – Definition

- Mean Opinion Score (MOS) is a subjective parameter
  - Perceived quality is usually scored in a five rank scale.
- The only **ITU model** for **parametric** MOS estimation in **video services**.
  - Oriented to **video-conference** services but de-facto used for other services too.
- Network parameter as **variables** in the model:
  - Video coding **bitrate**.
  - **Frame rate**.
  - End to end loss rate for IP packets, (**packet loss**).
- Model also needs a set of **coefficients** depending on: video codec, resolution and screen size.

Subjective quality assessment

- ITU Recommendation for subjective video quality assessment for multimedia applications. It describes:
  - Source signal.
  - Test methods.
  - Evaluation procedures.
  - Statistical analysis and reporting of results.

- In **absolute category rating** (ACR) test method, several video sequences are presented to human viewers who score them within a qualitative scale.

Bad	*Poor*	*Fair*	*Good*	*Excellent*

Encoding - Experiment

- Configurations for video services need to be adapted to bitrate limitation.
- Since low frame rate video must be considered, both **still image sequence** transmission and **regular video encoding** are under study.
- Work settings:

Setting	Values	Unit
Resolution	320x180 160x90	px
Encoding	JPEG, JPEG2000 H.264	-
Frame rate	1-25	fps
Bitrate	6, 12	kbps

Conclusion

- Underwater channel is very unfriendly
- Terrestrial wireless techniques must be adapted
- Quality is not perceived by viewer the same way as in videoconferencing/TV
- Video, even with low resolution and fewer frames per second, is considered better than still images