Optical Communication System for an Underwater Wireless Sensor Network

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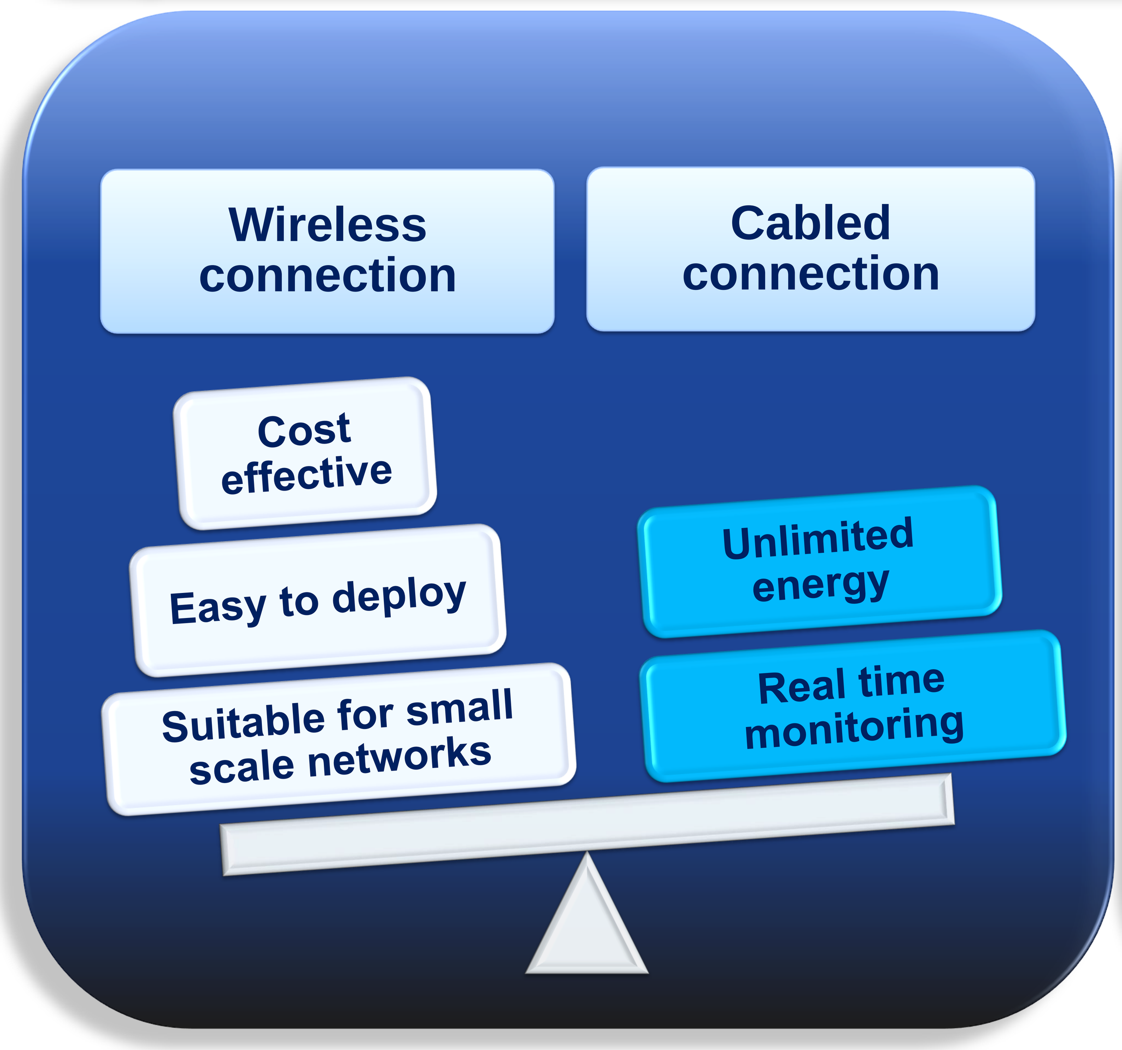
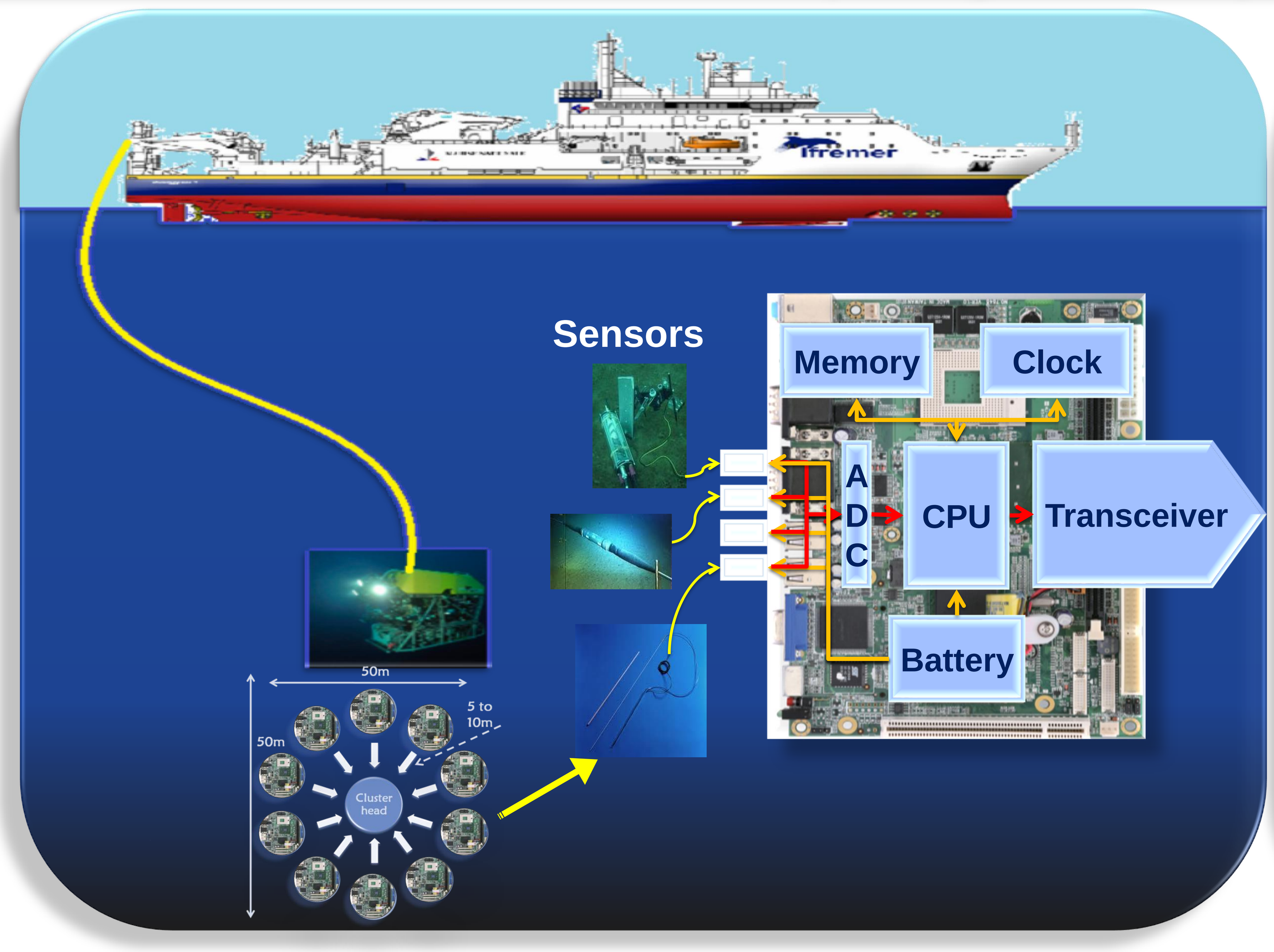
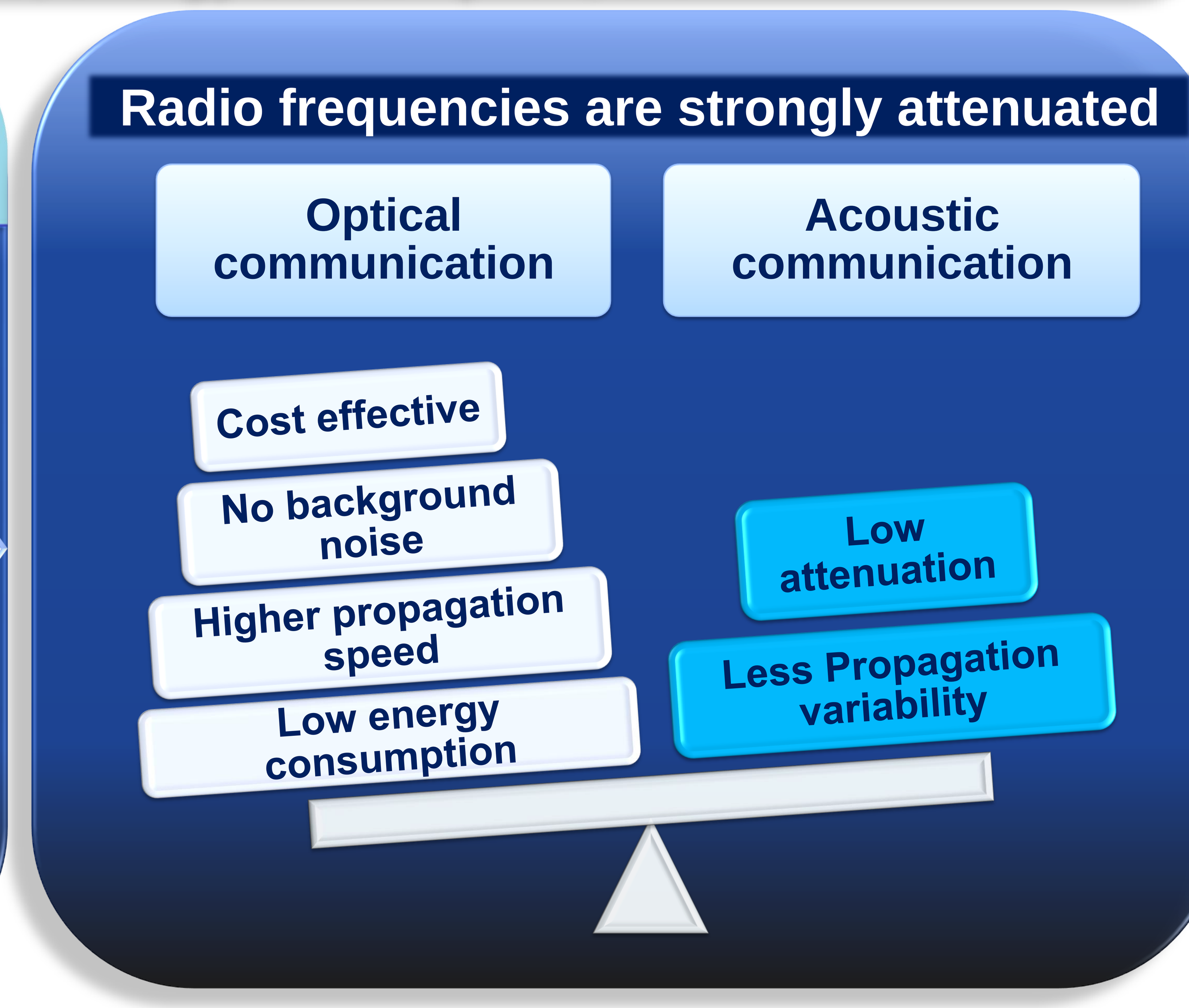
Underwater wireless sensor network (UWSN)

- An innovative method for oceans exploration.
- It is composed of several multi-functioning devices called “nodes” to which multiple sensors could be linked.
- Each node collects the data from the sensors, processes them and routes them to the other network nodes.
- An important step in the implementation of an UWSN is the design of an adequate transmitter/receiver system that can overcome the large number of problems that faces underwater communication such as propagation delays, energy consumption, etc.







Propagation

Absorption and scattering affect underwater optical signal propagation.

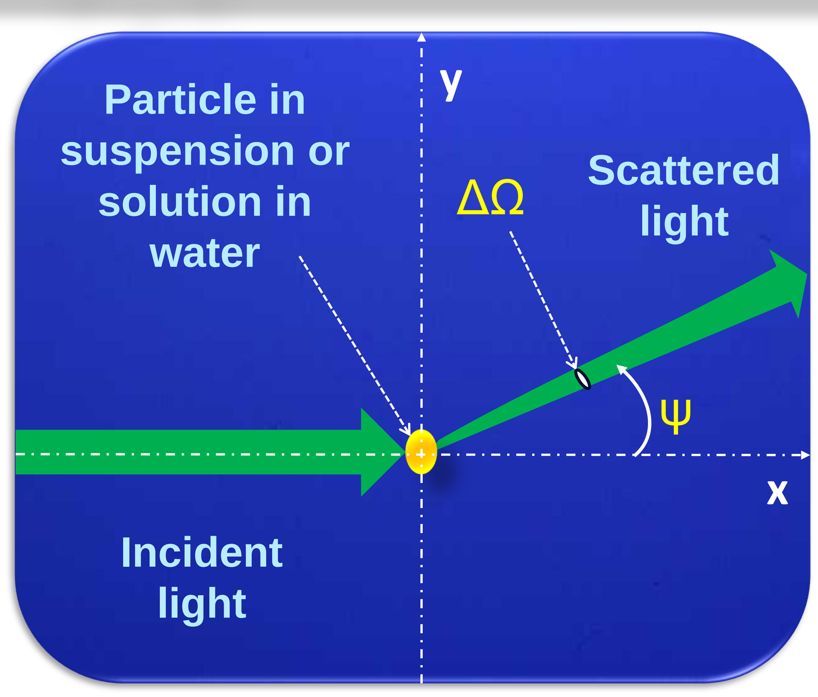
- **$a(\lambda)$ the spectral coefficient of absorption** (m^{-1})
- **$\beta(\theta)$ the volume scattering function (VSF)** ($m^{-1}sr^{-1}$)

Integrating the VSF over all directions gives the spectral scattering coefficient $b(\lambda)$.

- **$b(\lambda) = 2\pi \int (\beta(\Psi, \lambda) \sin(\Psi) d\Psi)$** ($m^{-1}$)

The sum of $a(\lambda)$ and $b(\lambda)$ gives the spectral beam attenuation coefficient $c(\lambda)$.

- **$c(\lambda) = a(\lambda) + b(\lambda)$** ($m^{-1}$)



Monte Carlo simulator

Step size → Weight drop → Angle scattering generation

Step size: $\delta = -\log(\chi_\delta)/c$

Beer-Lambert law:
-δ: distance travelled by a photon before reaching a particle.
-X_δ is a random variable

Weight drop: $W_{post} = W_{pre}(1-a/c)$

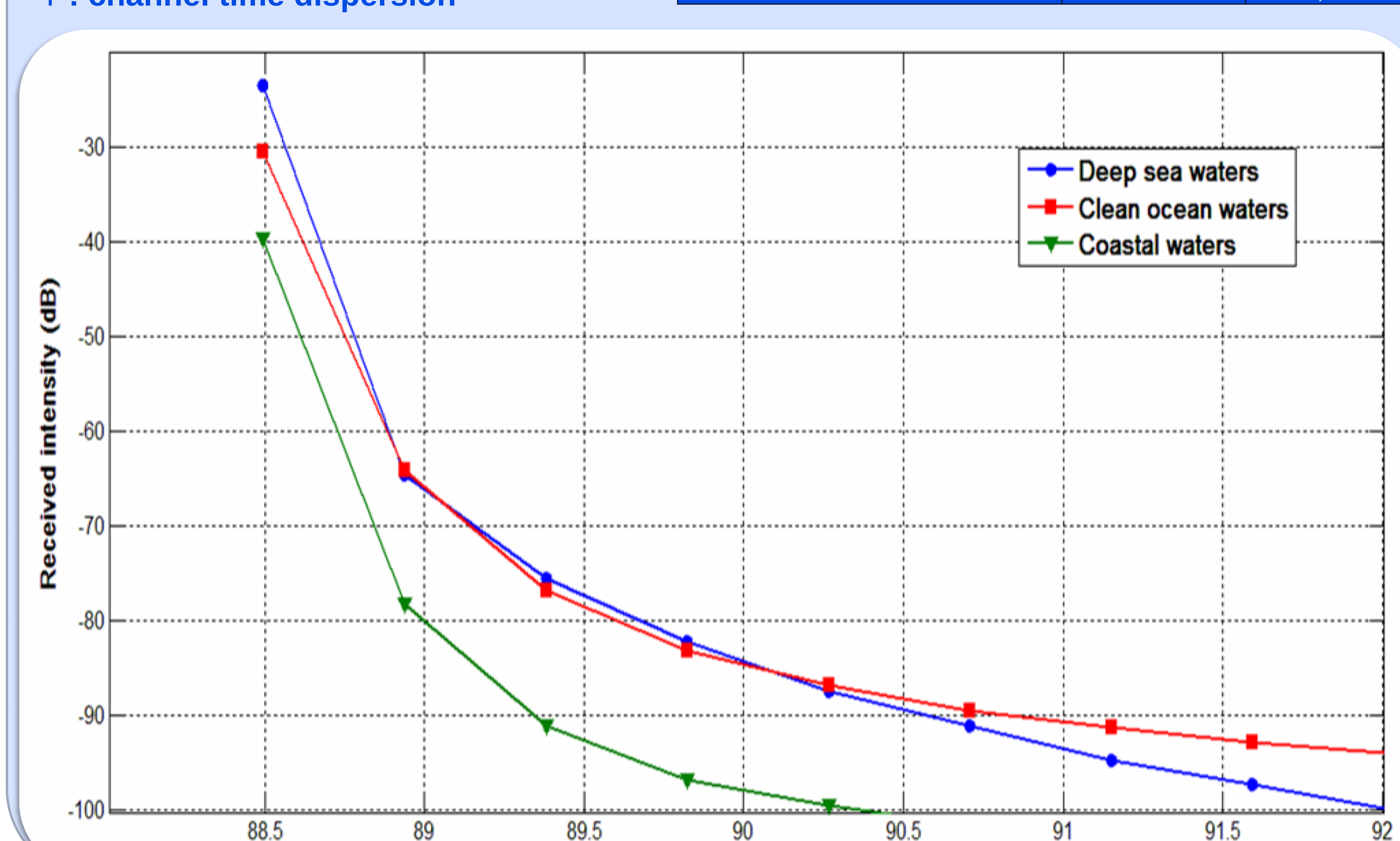
-W_{post} and W_{pre} are the photon weight s respectively before and after the collision with the particle

Angle scattering generation: Two term Henyey-Greenstein model

Channel time dispersion

- Transmitted power **P=0.1 W**
- Receiver’s lens aperture diameter **D=20 cm**
- Initial beam divergence angle=**20°**
- T : **channel time dispersion**

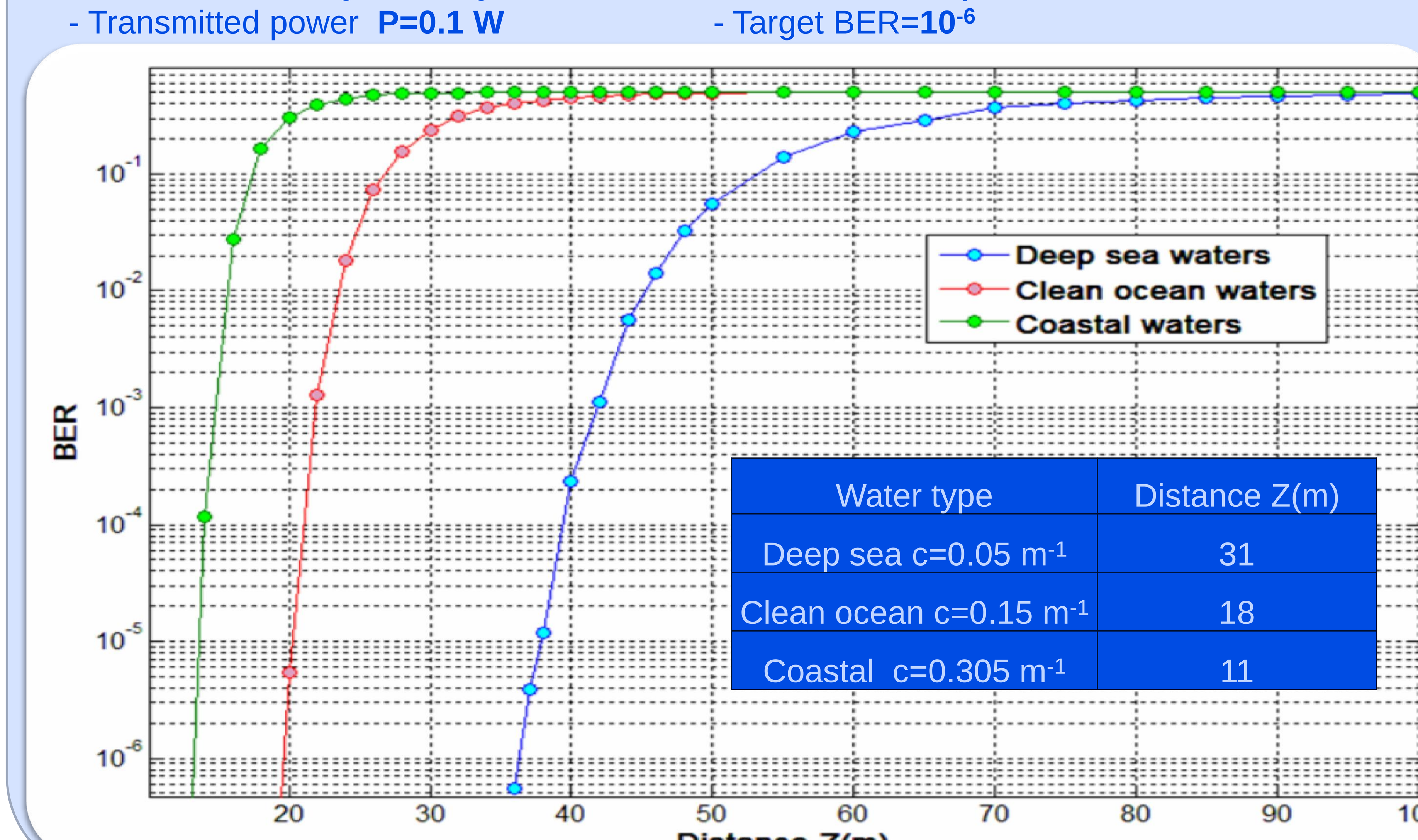
Water types	I loss (dB)	T (ns)
Deep sea c=0.05 m^{-1}	-23.5	0,21
Clean ocean c=0.15 m^{-1}	-30.41	0,26
Coastal c=0.305 m^{-1}	-39.74	0,28



BER Performance

Modulation OOK → Transmitter LED → Receiver PIN → Demodulation OOK

- Receiver’s lens aperture diameter **D=20 cm**
- Initial beam divergence angle=**20°**
- Transmitted power **P=0.1 W**
- Data rate=**1 Gbps**
- Target BER=**10^{-6}**



Water type	Distance Z(m)
Deep sea c=0.05 m^{-1}	31
Clean ocean c=0.15 m^{-1}	18
Coastal c=0.305 m^{-1}	11

Conclusions

- We evaluated the optical underwater channel by elaborating a realistic Monte Carlo simulator that takes into account the medium, transmitter and receiver characteristics.
- We demonstrated that the channel time dispersion is negligible for data rates up to 1 Gbps in most practical cases.
- Through the BER study, we showed that we can reach up to 31 m with a LED/PIN transceiver in deep sea waters.

Perspectives

- Replacing the PIN diode with more adequate photo-detectors.
- Developing efficient coding and modulation techniques to improve the system performances/increase the link distance.
- Making a test-bed for the studied communication link.