Riding the Stress Wave: Integrated Monitoring, Communications, and Networking for Subsea Infrastructure

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Courtesy to UH students, Debing Wei, Li Yan, Steban Soto, Chaoxian Qi, Drs. Jiefu Chen, Aijun Song, and Gangbing Song

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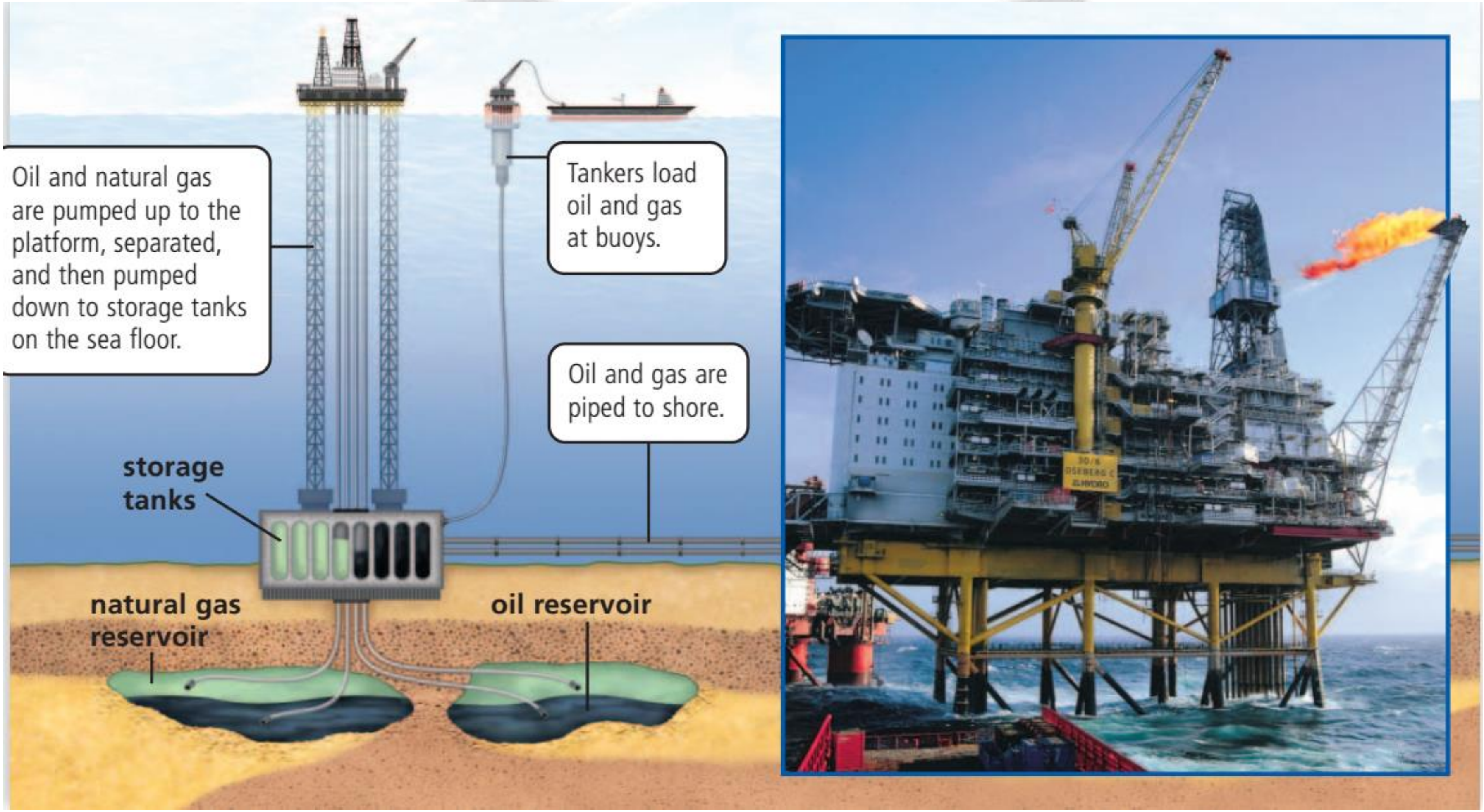
Outline

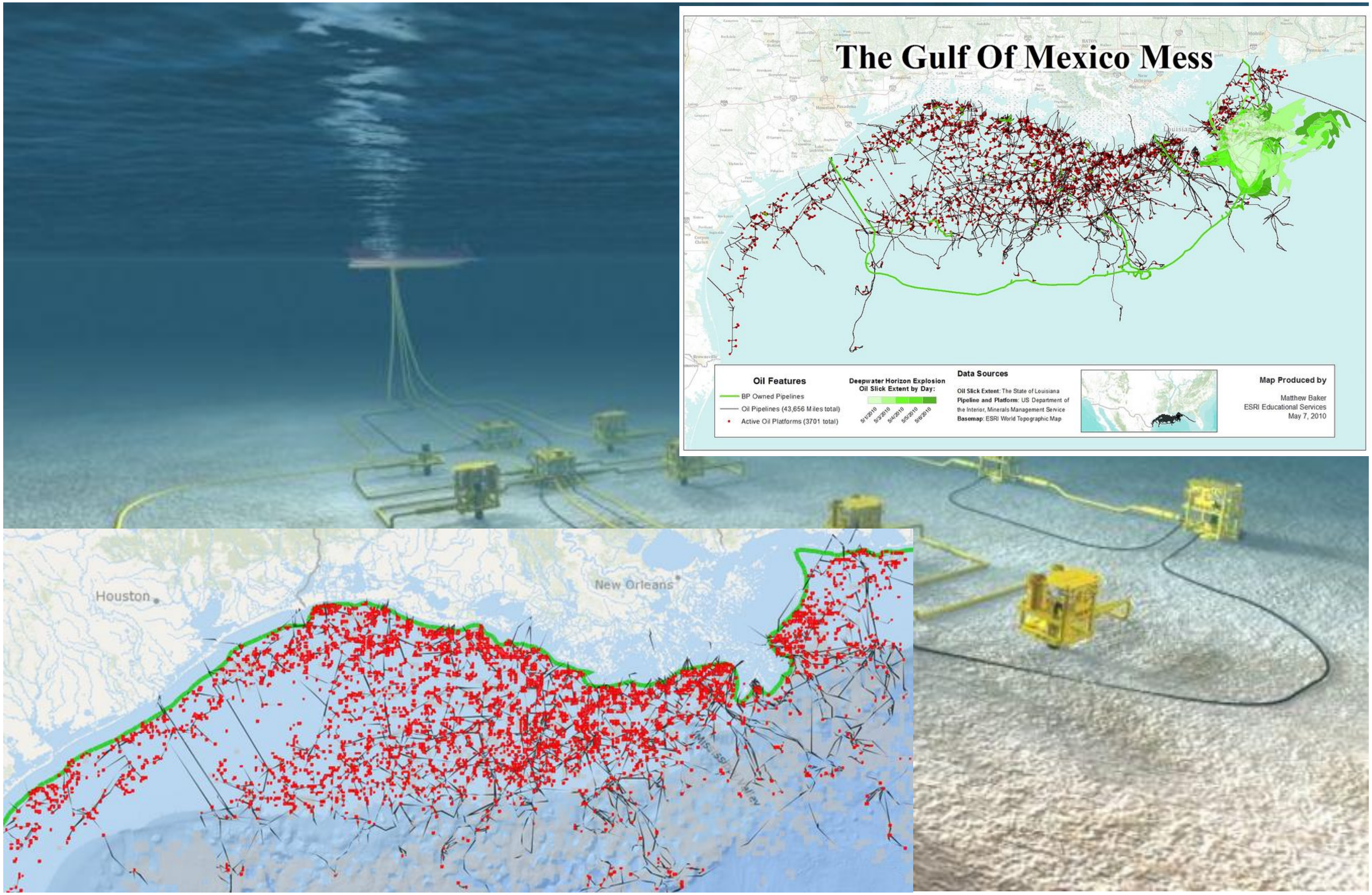
- Background
- Stress Wave Channel Capacity Estimation
- Stress Wave Assisted Hybrid Subsea Networks
- Stress Wave Platform Development
- Conclusion

Offshore Drilling

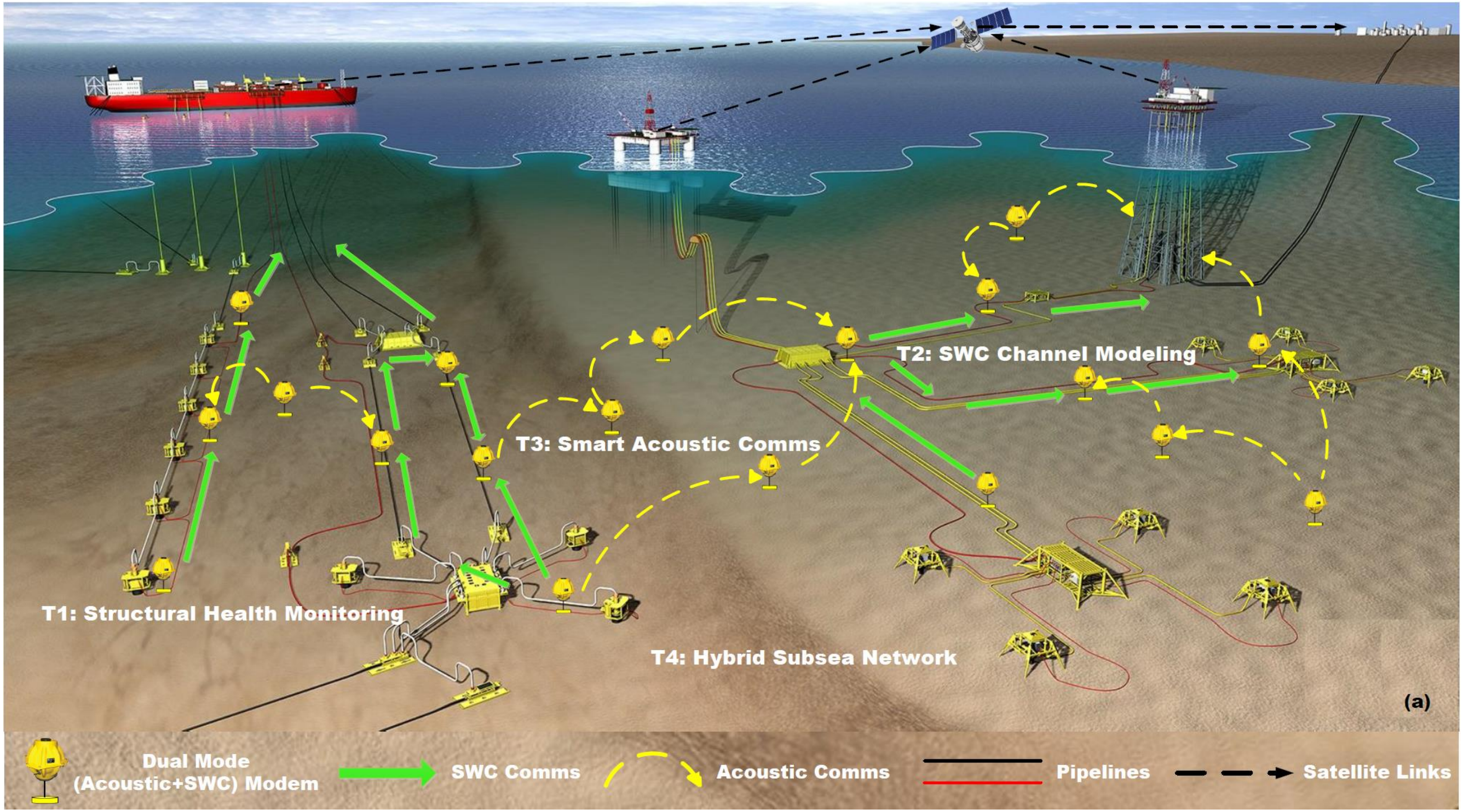


BP's "Deepwater horizon" oil spill

Fire boat response crews battle the blaze of the off shore oil rig Deepwater Horizon, in the Gulf of Mexico, April 21, 2010.


The Gulf Of Mexico Mess
Oil Features
BP Owned Pipelines
Oil Pipelines (43,656 Miles total)
Active Oil Platforms (3701 total)
Deepwater Horizon Explosion Oil Slick Extent by Day:
5/1/2010
5/3/2010
5/4/2010
5/5/2010
5/6/2010
Data Sources
Oil Slick Extent: The State of Louisiana
Pipeline and Platform: US Department of the Interior, Minerals Management Service
Basemap: ESRI World Topographic Map
Map Produced by
Matthew Baker
ESRI Educational Services
May 7, 2010
Houston
New Orleans

Stress Wave Assisted Communications



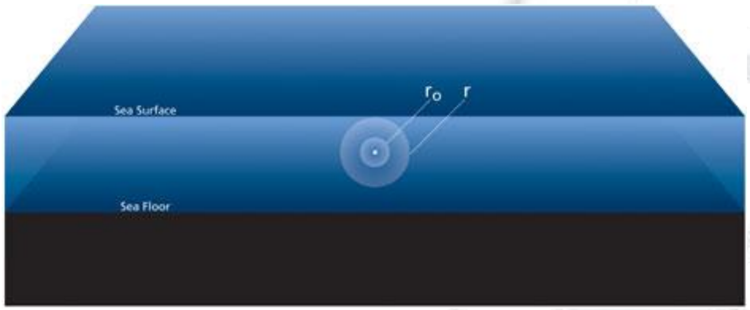
Subsea SYSTEMS INSTITUTE

Stress Wave Assisted Communications in Subsea Environments

Stress Wave Channel Capacity

Sound Propagation Schemes

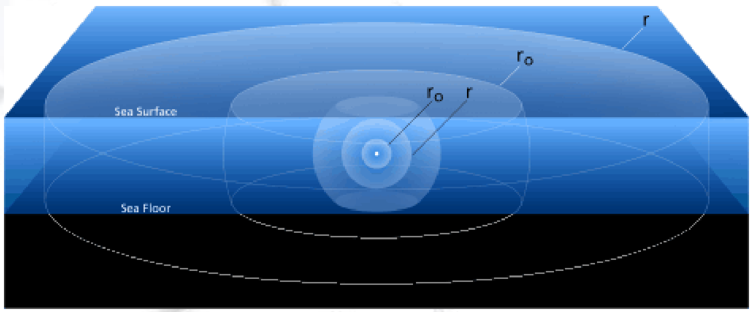
- Spherical Spreading for Deep Water



$$P = 4\pi r^2 I$$

P: transmit power
I: power density
r: transmission range

- Cylindrical Spreading for Shallow Water

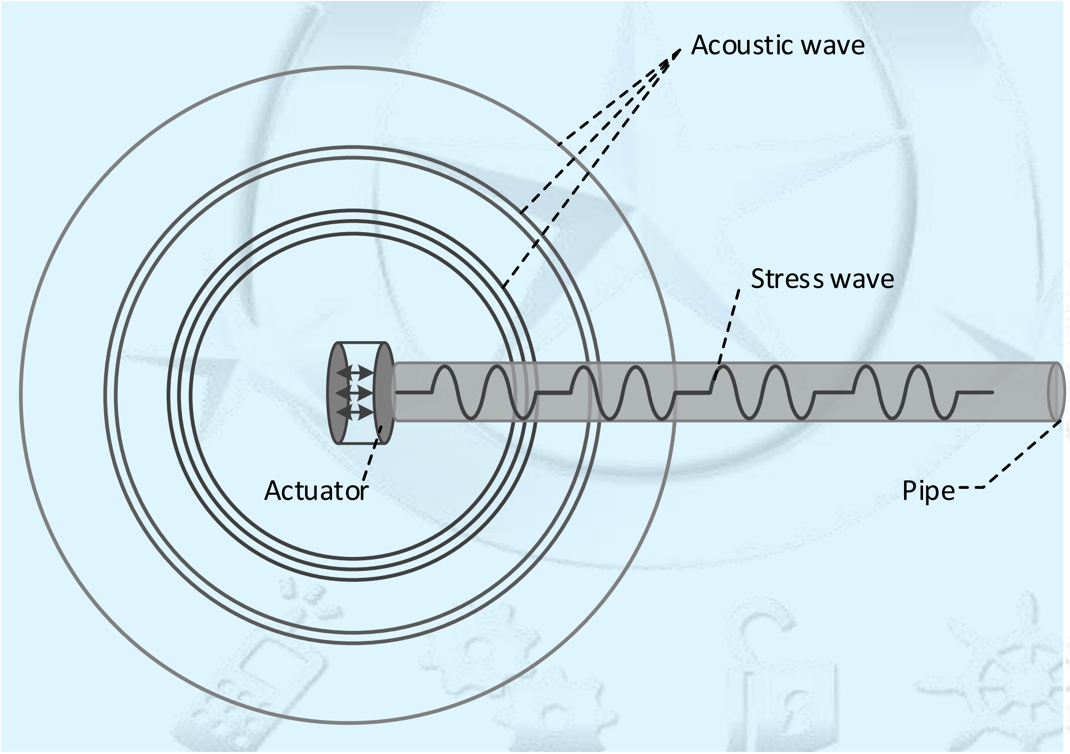


$$P = 2\pi r H I$$

H: height from seafloor to surface

Sound Propagation Schemes

- Acoustic wave guide

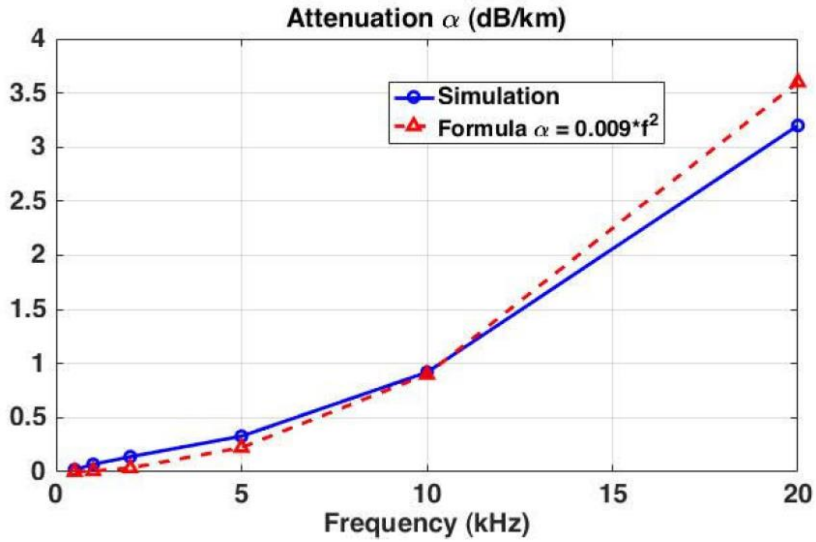


Spreading loss can be significantly reduced!

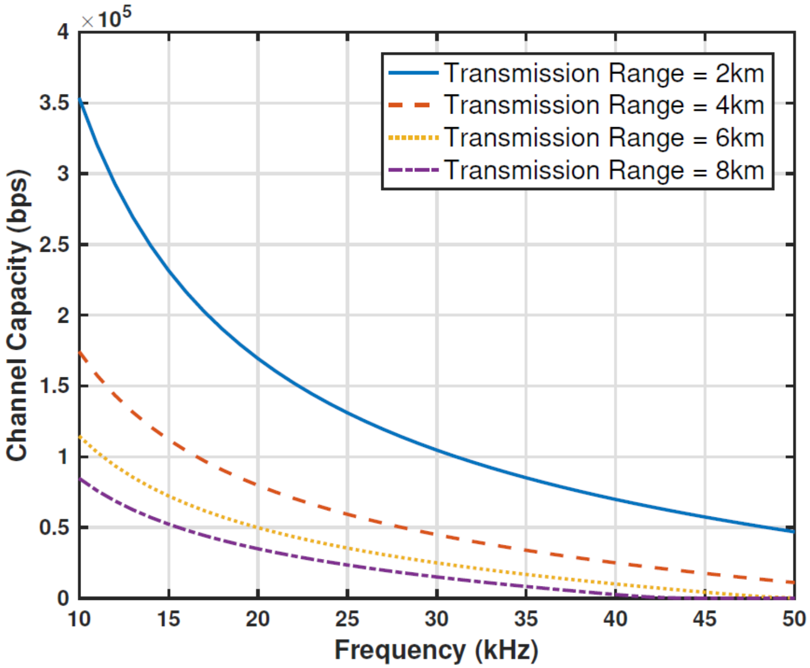
Stress Wave Channel Capacity Estimation

- Path loss model

$$10\log TL(d,f) = k \cdot \log(d) + d \cdot \alpha(f) + A$$



Absorsation loss:
$$\mathbf{10\log}\boldsymbol{TL(d,f) = 0.009f^2d}$$



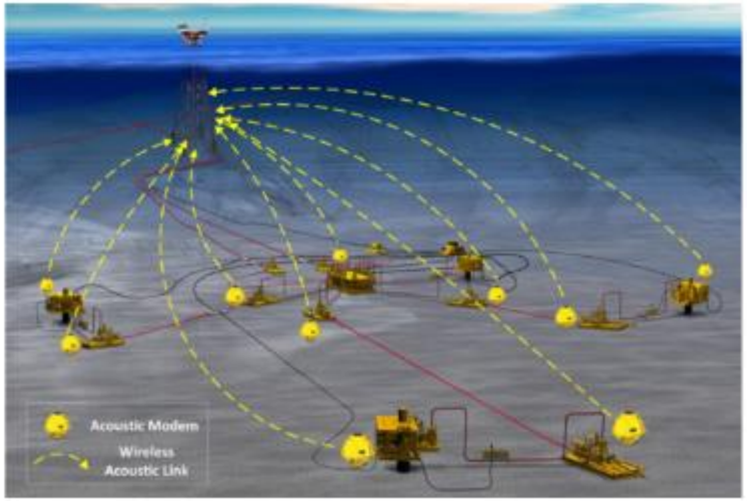
(b) Channel capacity under different transmission range with transmitting power = 180 dB re μPa.

Channel Capacity

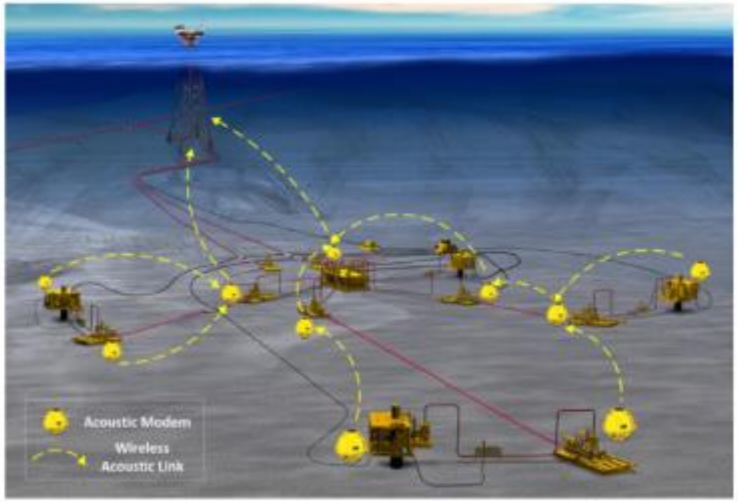
Hybrid Subsea Networks

Hybrid Subsea Netwok

One Hop



Multi-hop



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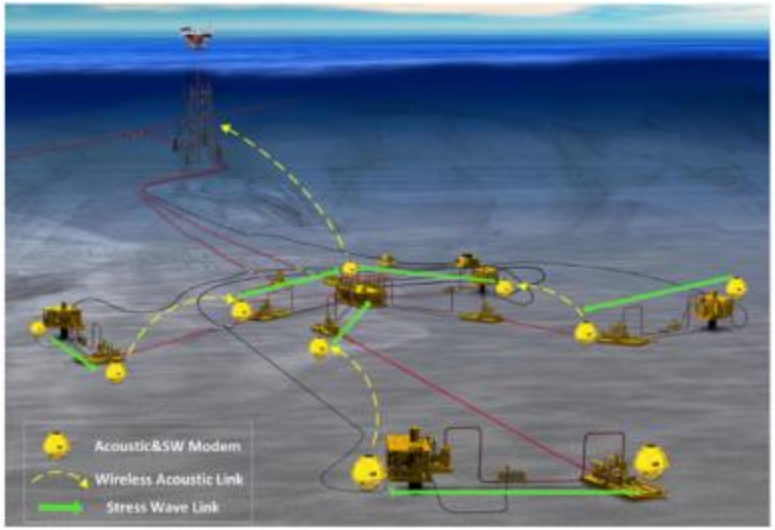
Hybrid



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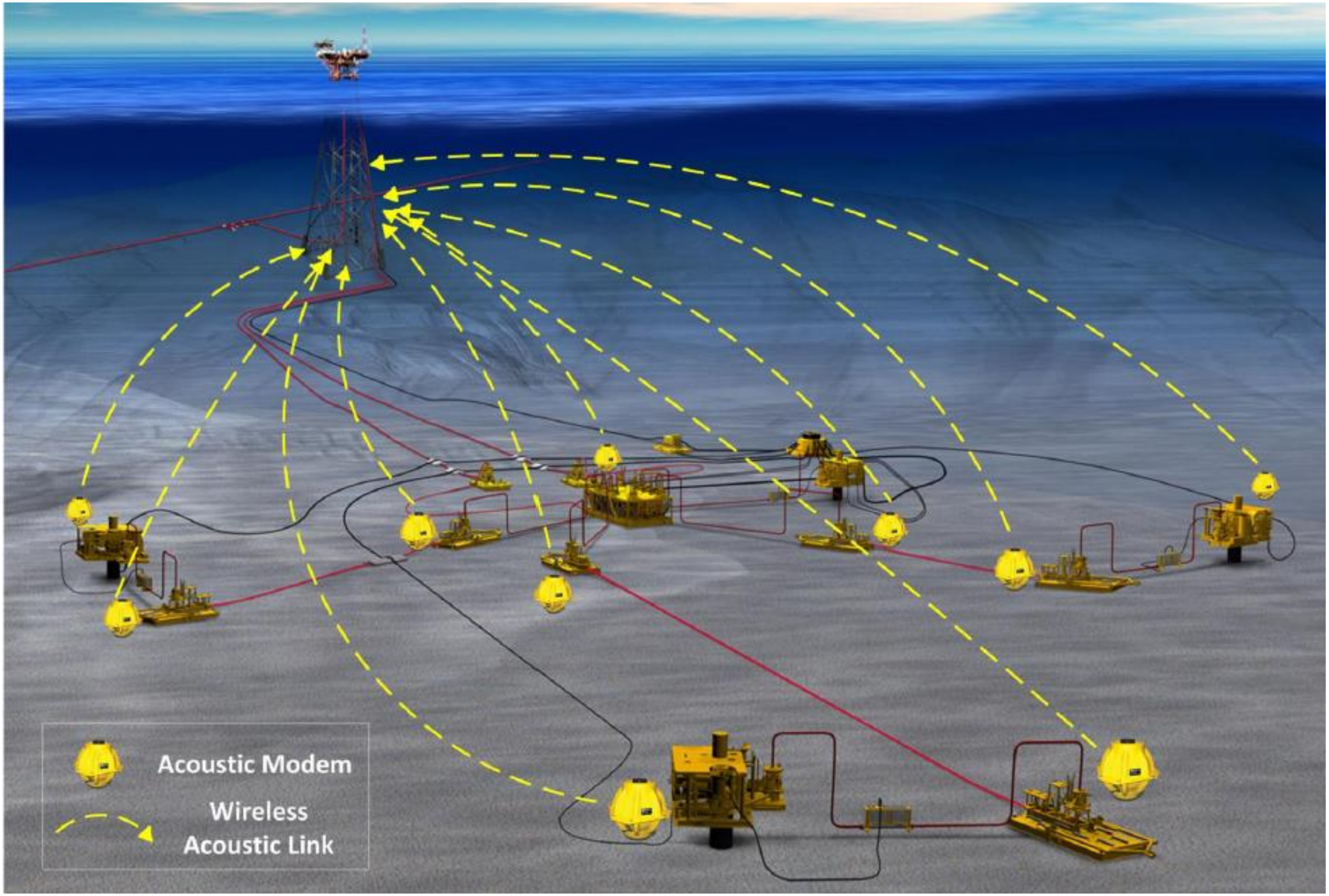
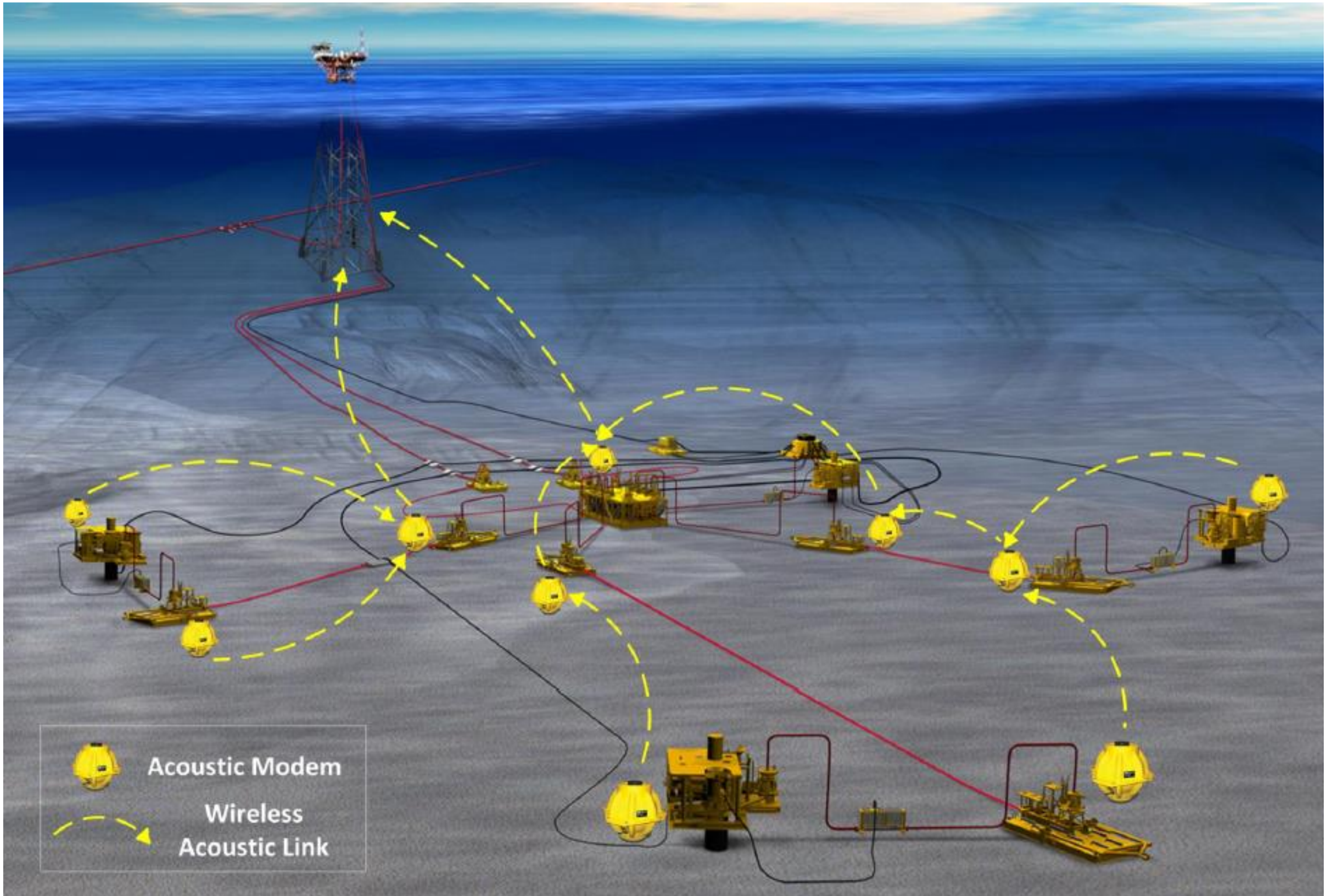
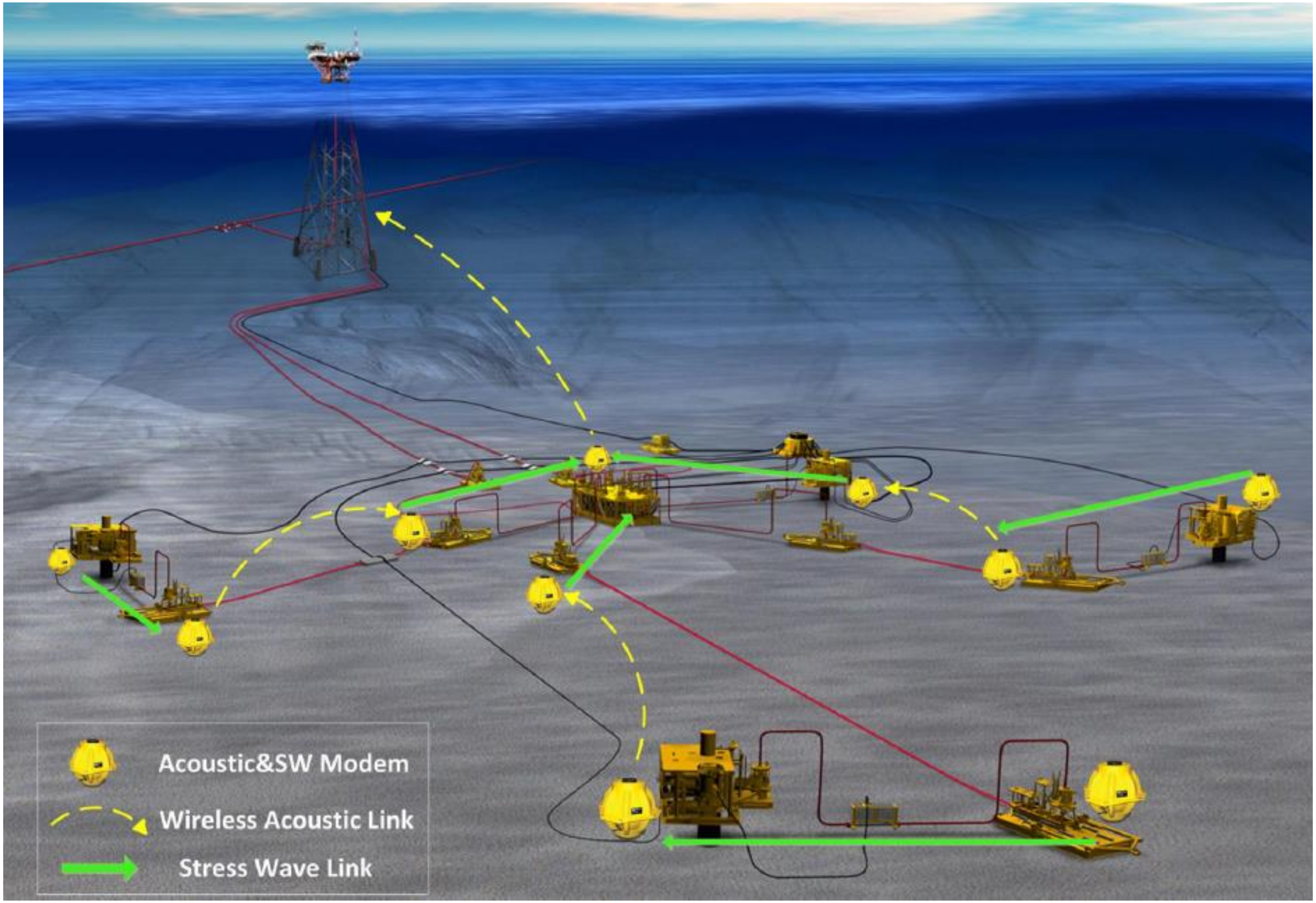
One Hop



Multi-hop

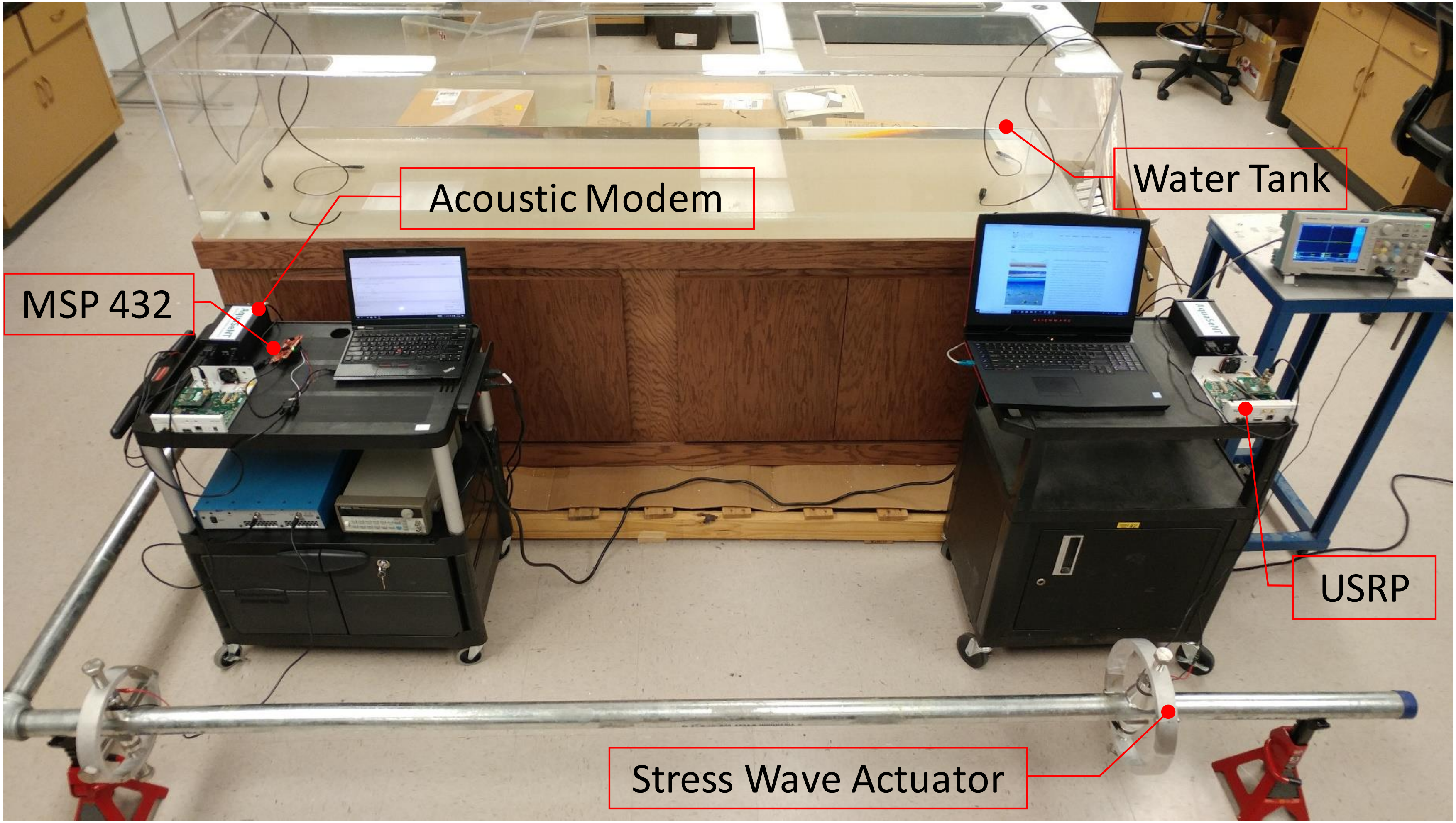


Hybrid



Stress Wave Testbed Development

Testbed


Acoustic Modem
Water Tank
MSP 432
USRP
Stress Wave Actuator

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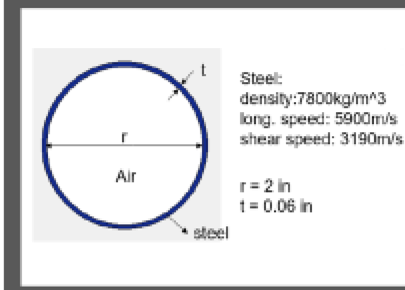
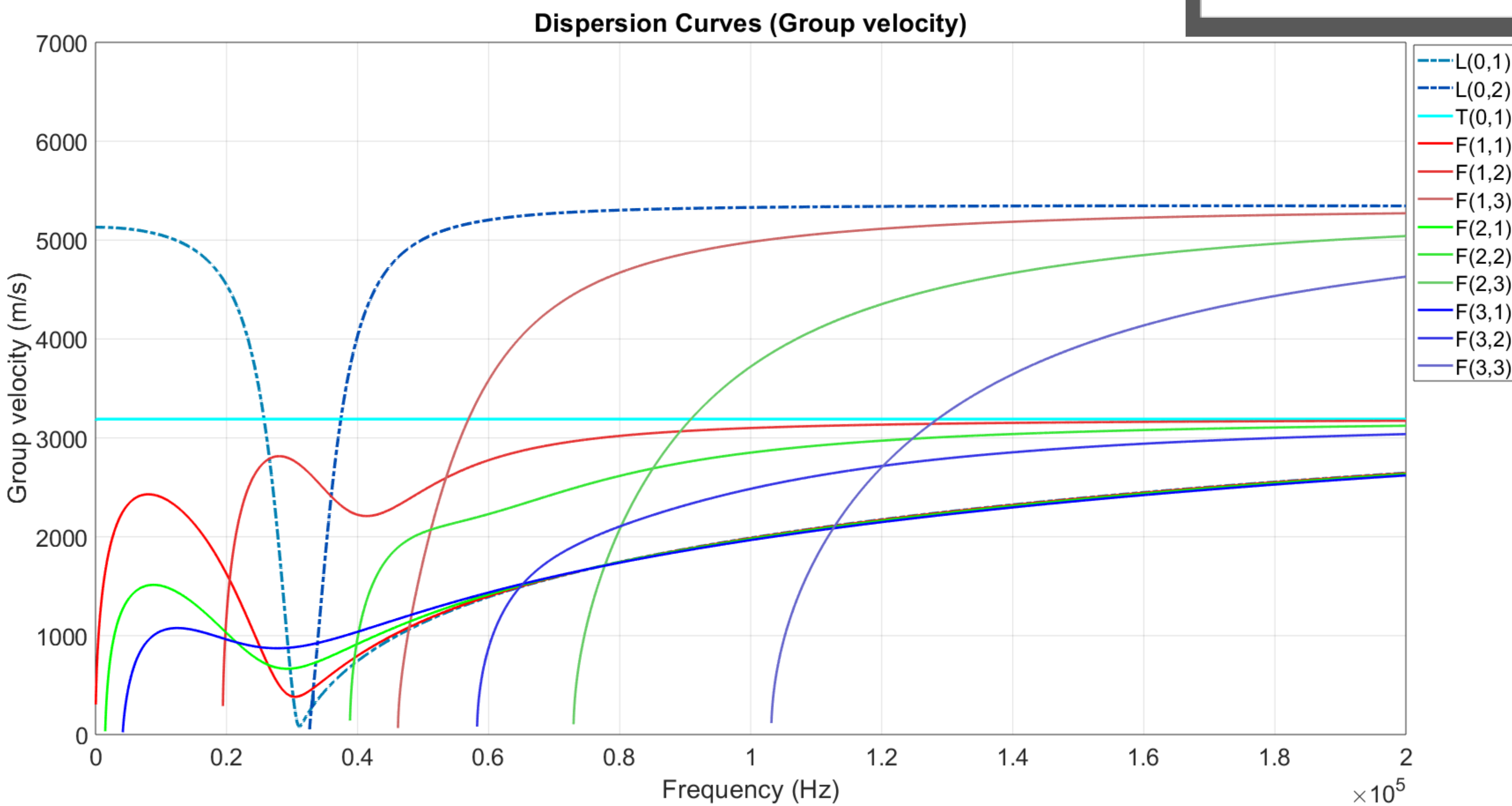
Dispersion analysis for pipe geometry



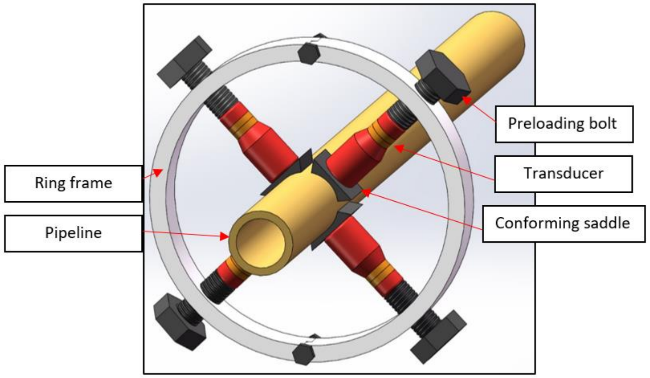
Group Velocity Dispersion Curves



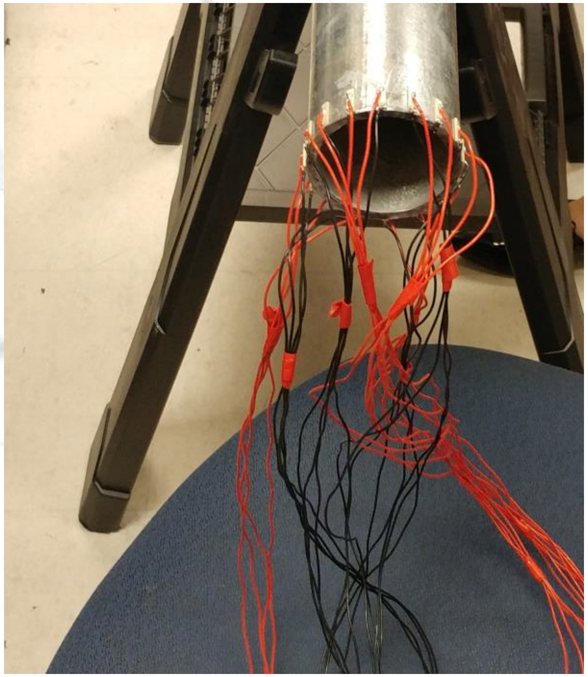
Alleyne, D. N., and P. Cawley. "The excitation of Lamb waves in pipes using dry-coupled piezoelectric transducers." Journal of Nondestructive Evaluation 15.1 (1996): 11-20

PZT Transducer Design

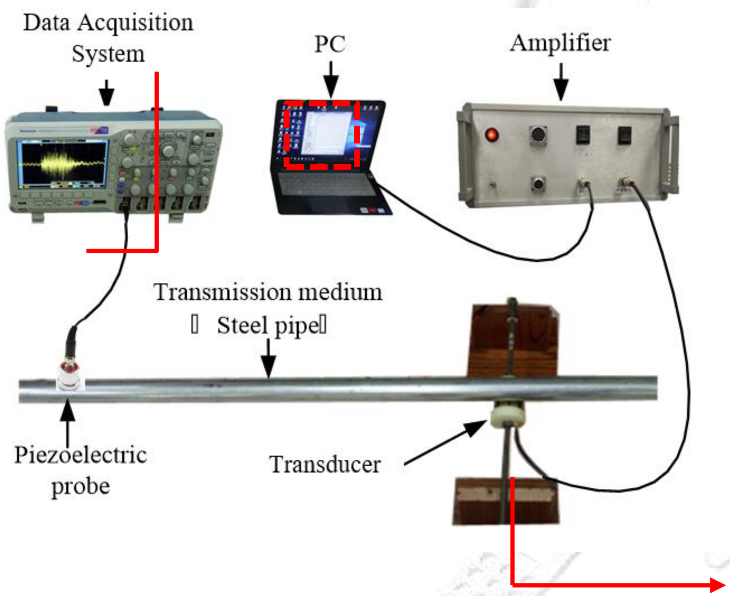
- First design



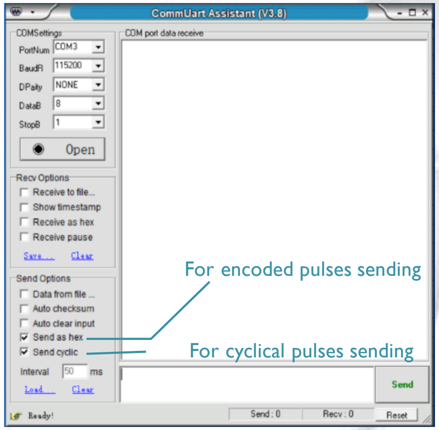
- Second Design



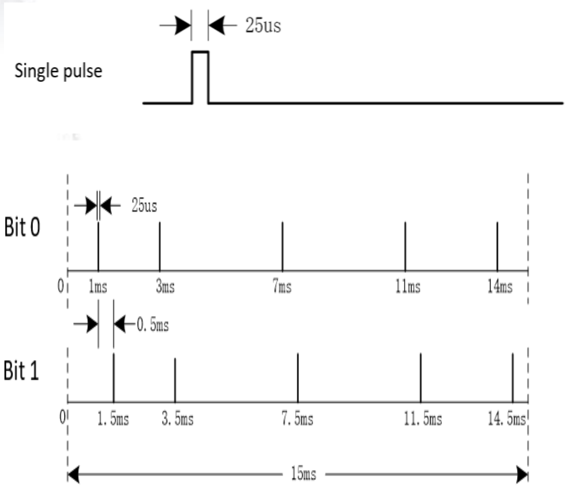
Pulse Position Modulation (PPM)



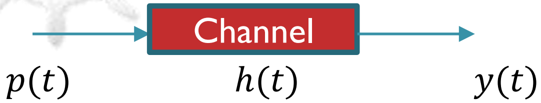
Eight piezoelectric ceramic plates in parallel with tangential polarization.



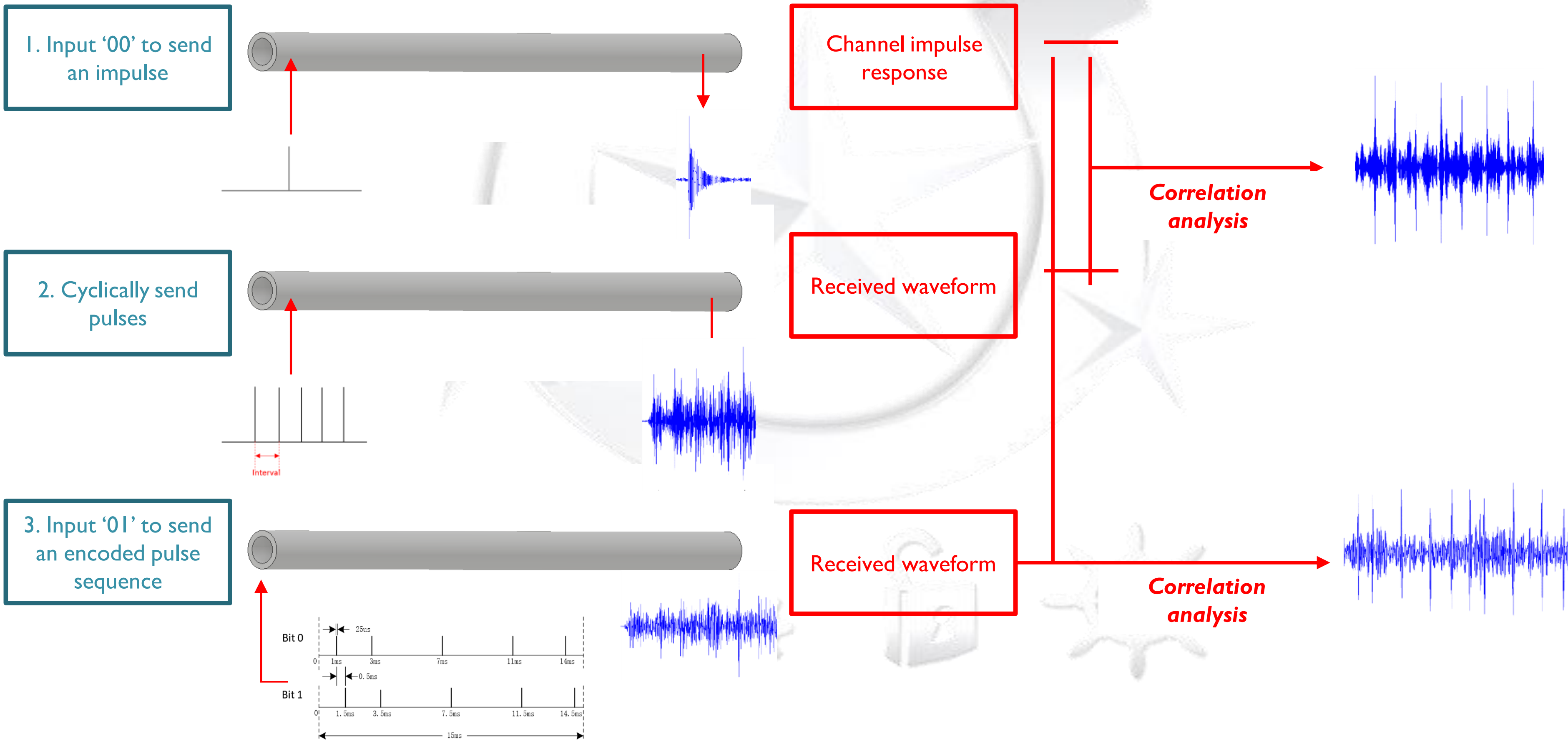
Coding format



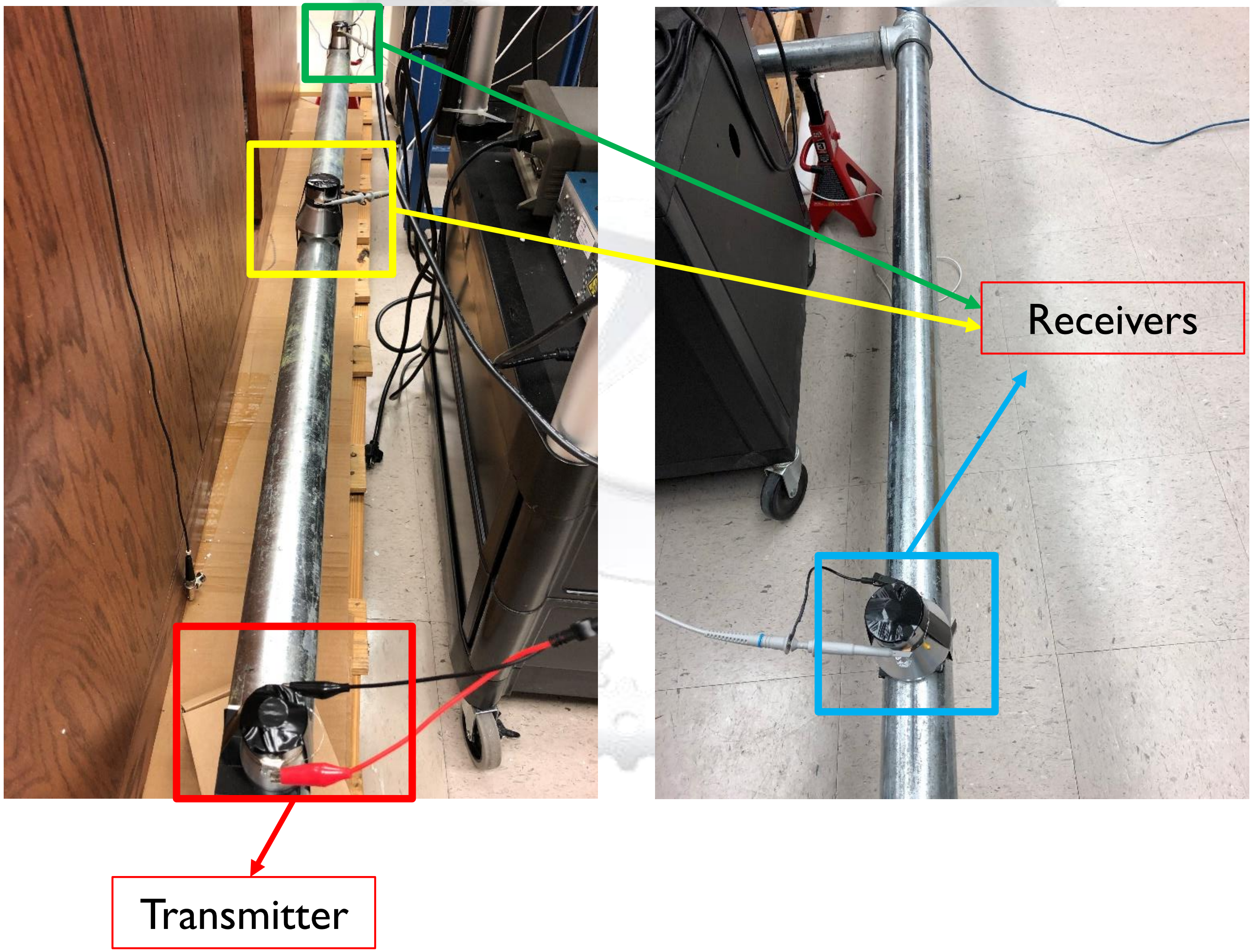
Correlation analysis



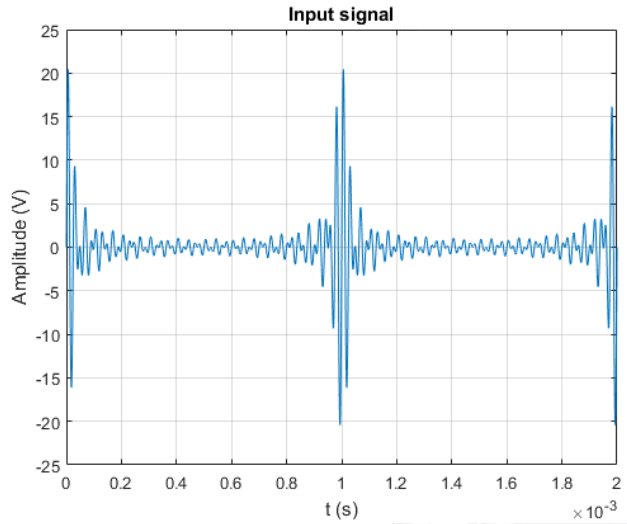
Experiment for PPM

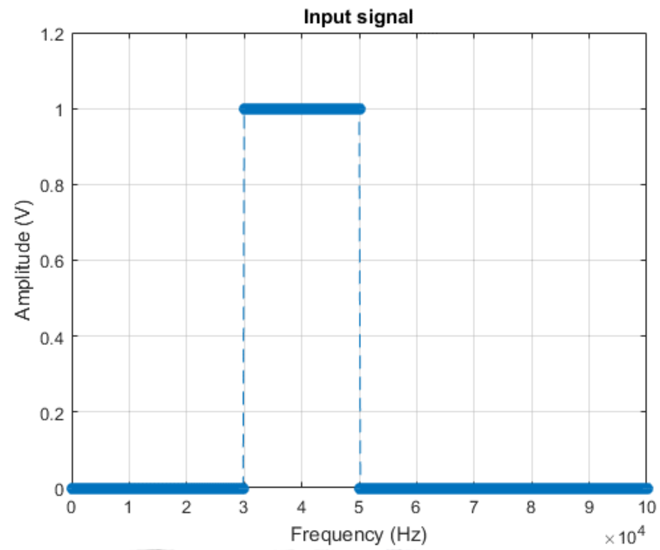


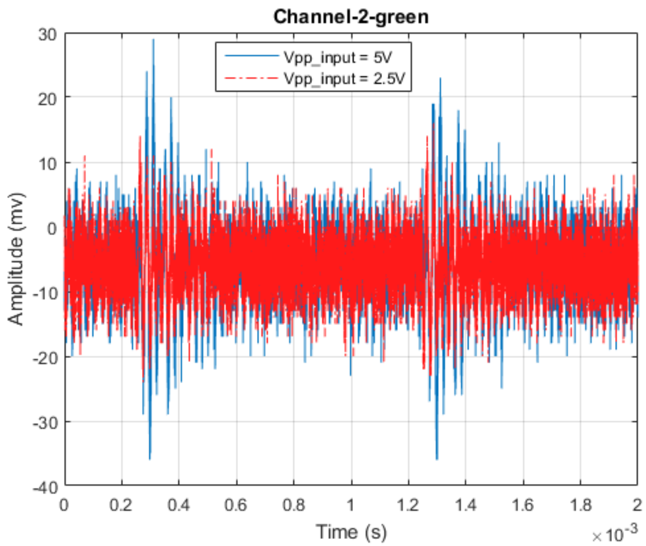
Experiment setup

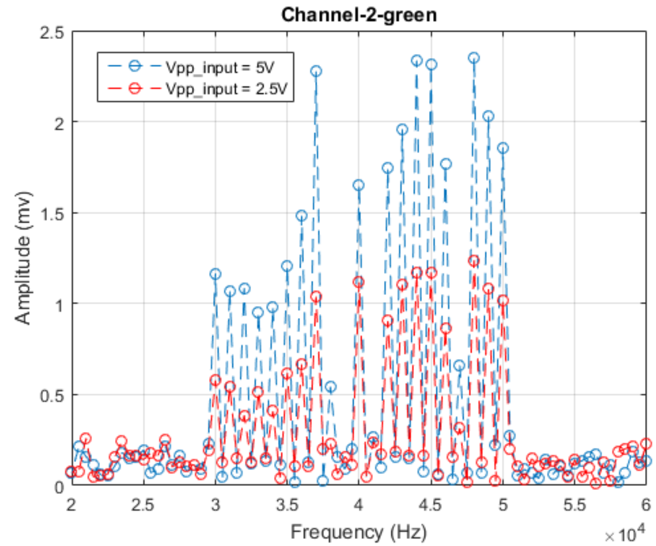


Linearity analysis

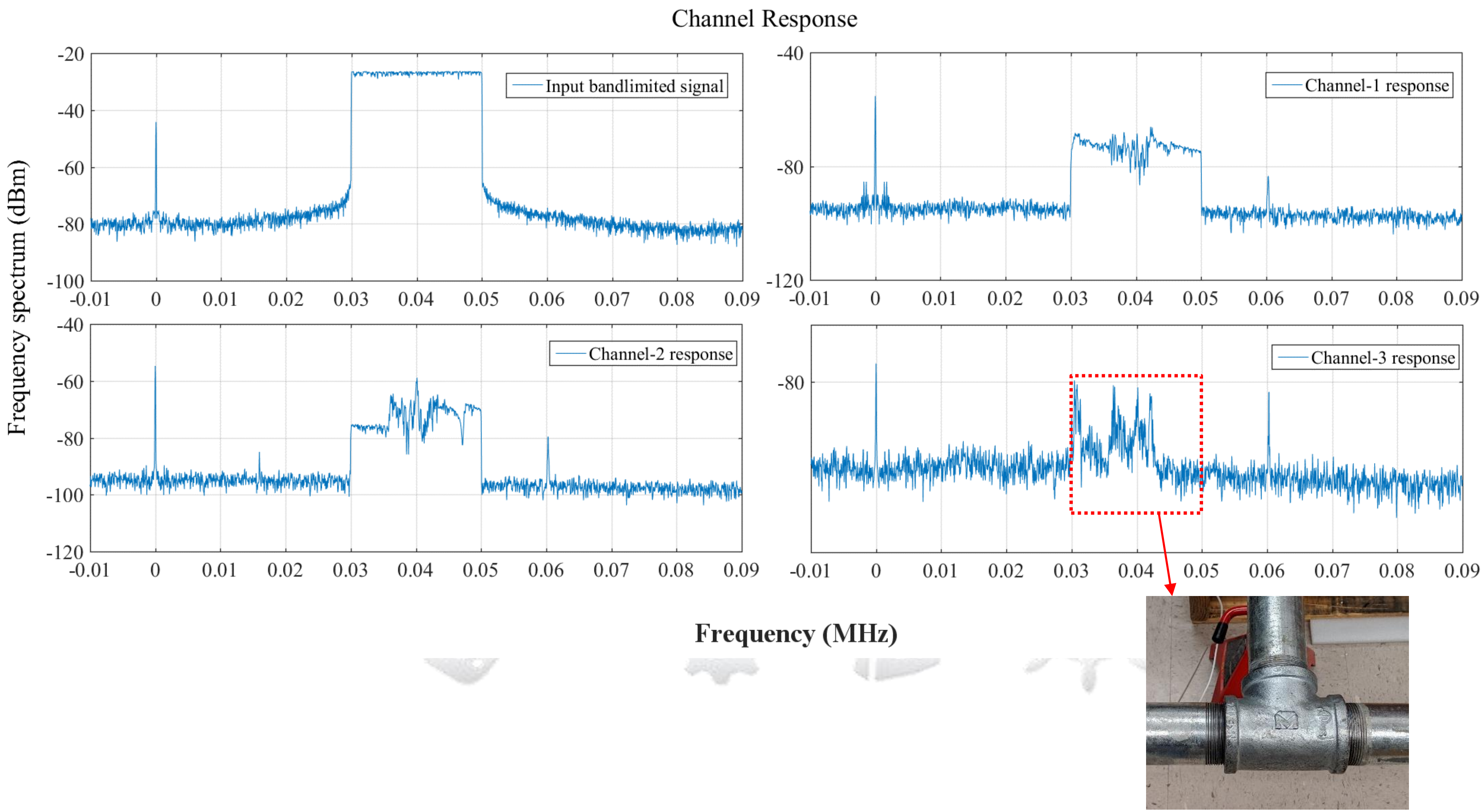








Channel Response



Conclusions

- The offshore infrastructures can be leveraged for stress wave communications.
- Combining different types of communication techniques can significantly enhance network performance in subsea environments.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