Towards Underwater Video Transmission

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Outline

1. Overview
2. Previous work
3. Contributions
   - Doppler compensation algorithm
   - MPEG-4 error resilience tools
   - In-air Experimental Tests
4. Conclusions

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Problem statement

UNDERWATER CHANNEL

Limited bit-rate capacity

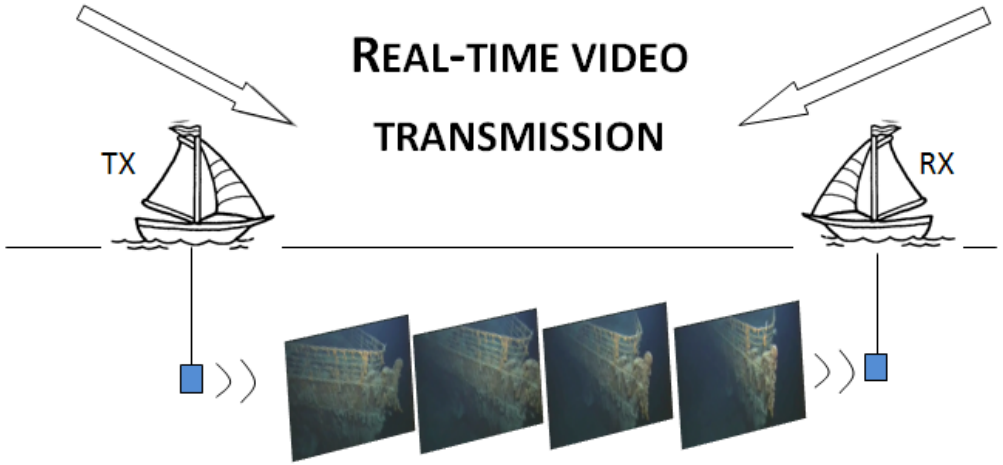
VIDEO COMPRESSION

Reduce the bit-rate needed

MODULATION TECHNIQUE

Bandwidth-efficient modulation to increase bit-rate supported

REAL-TIME VIDEO TRANSMISSION



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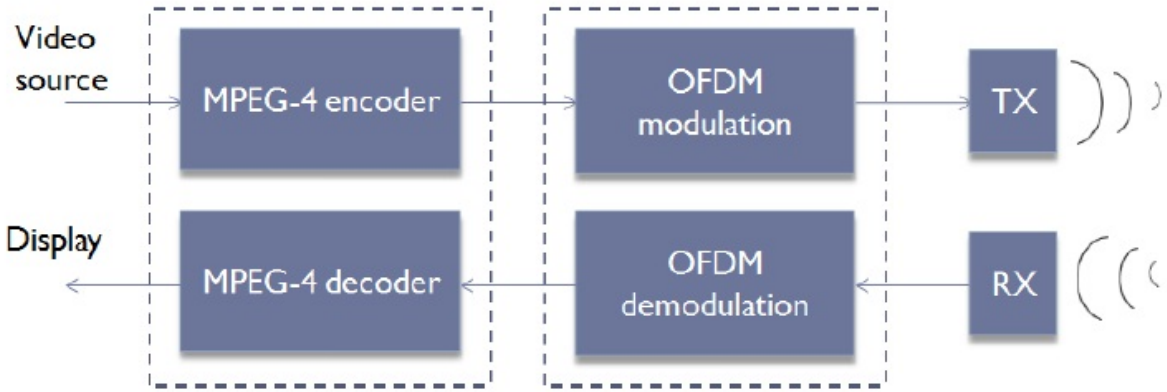
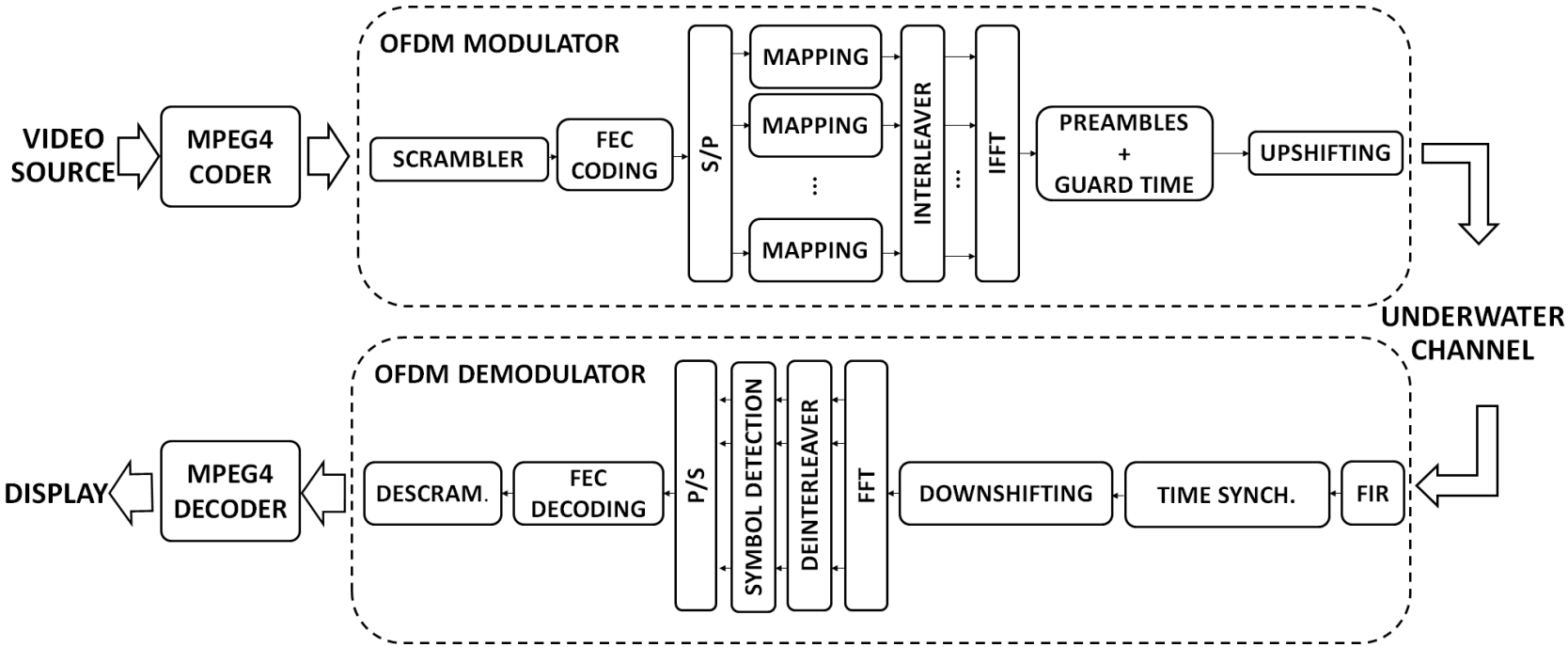
OFDM + MPEG4 approach

- Video compression technique: **MPEG-4 standard** $\longrightarrow$ **10 kbps**
- Bandwidth efficient modulation: **Orthogonal Frequency-Division Multiplexing (OFDM)** $\longrightarrow\sim$ **90 kbps**



System design



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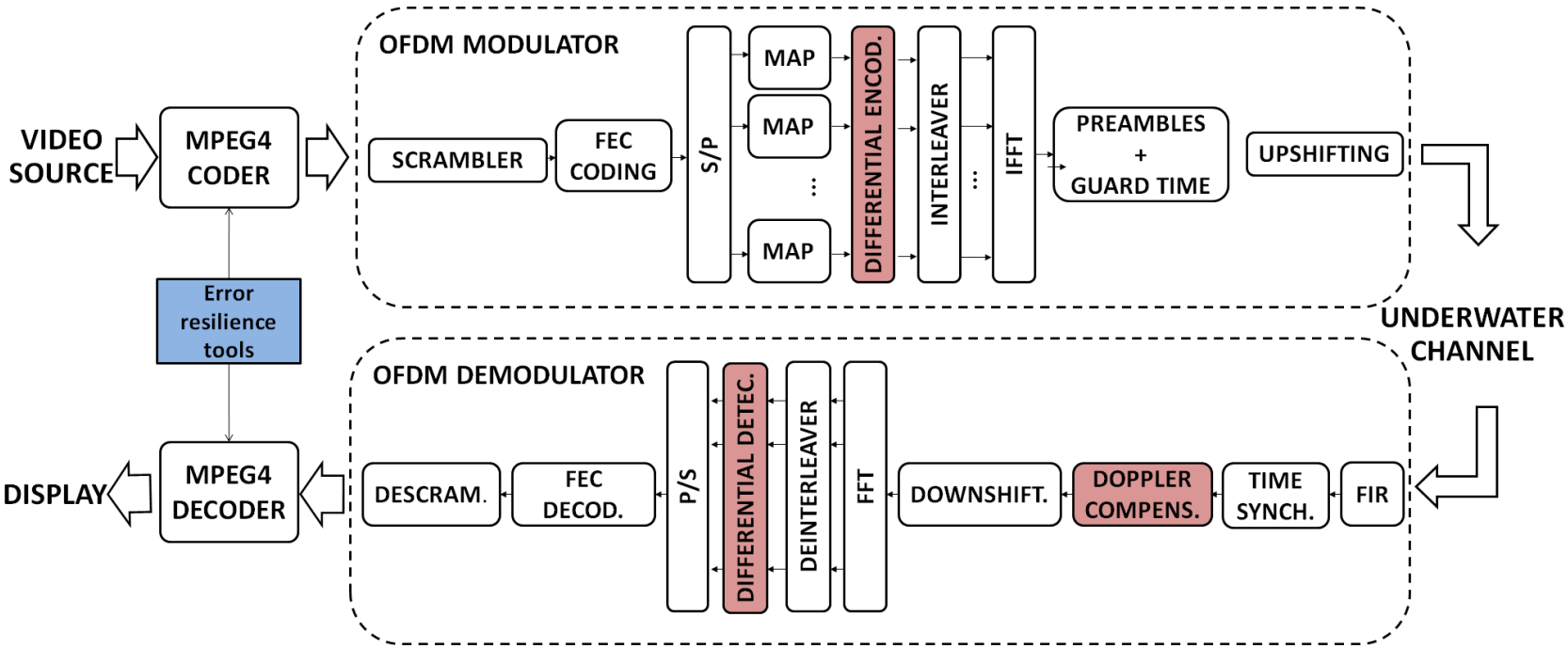
Two contributions

1. Doppler compensation algorithm + Differentially coherent detection
2. MPEG-4 error resilience tools



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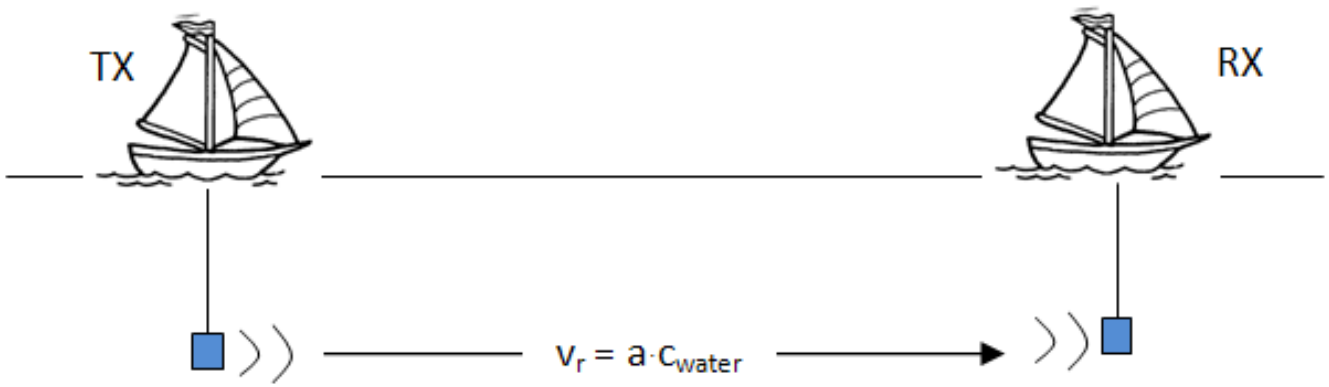
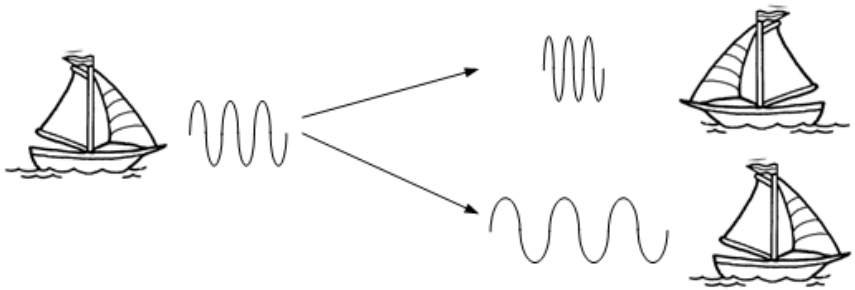
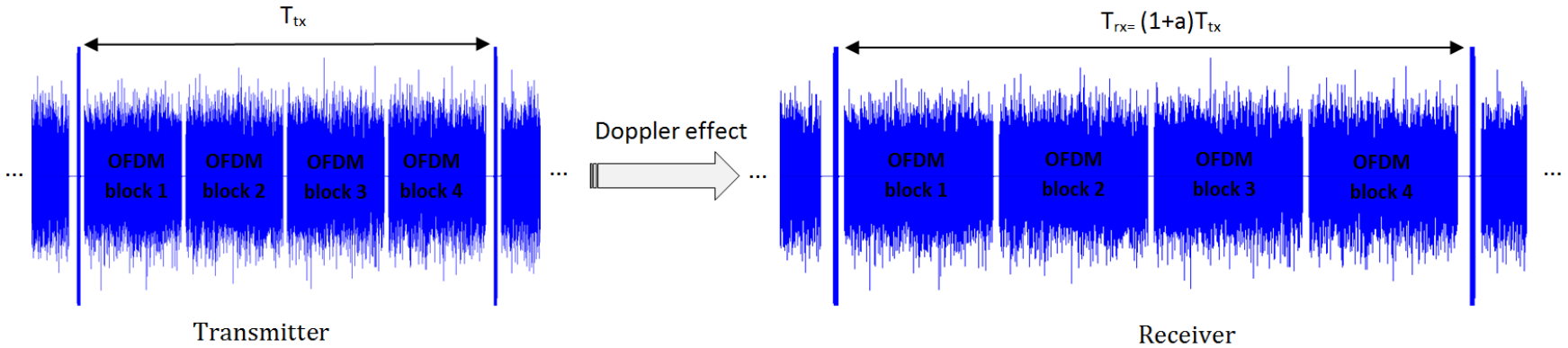
Doppler Effect



- The signal is scaled in time by the factor $(1 + a)$
- Each subcarrier experiences a frequency shift $e^{ja\omega_k t}$



Algorithm



1. Estimation of the Doppler factor using the measured time between adjacent preambles:

$$T_{rx} = T_{tx}(1+a) \qquad \Rightarrow \qquad a = \frac{T_{rx}}{T_{tx}} - 1 \tag{1}$$

2. Resample the received signal with the estimated resampling rate: $\tilde{z}(t) = \tilde{y}\left(\frac{t}{1+a}\right)$

Differentially coherent detection

Theorem

If the channel distortion is similar between adjacent subcarriers,

$H_k(n) \approx H_{k-1}(n) \qquad e^{j\theta_k(n)} \approx e^{j\theta_{k-1}(n)}$

differentially coherent detection is able to compensate for the amplitude and phase distortion

Fact

In our system, Doppler frequency shifts are similar between adjacent subcarriers: $e^{ja\omega_k t} \approx e^{ja\omega_{k-1} t}$

Corollary

Doppler frequency shifts will be compensated for at the differential detection process

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MPEG-4 error resilience tools: goal

Video Packet Splitting and Data Partitioning

They provide additional protection to the most important data of the video (motion and shape data), acting like an additional channel coding technique, but without adding too much overhead.

Benefits

We can **reduce the amount of conventional channel coding** (BCH codes) in order to increase the available data bitrate, while always maintaining a good visual quality.

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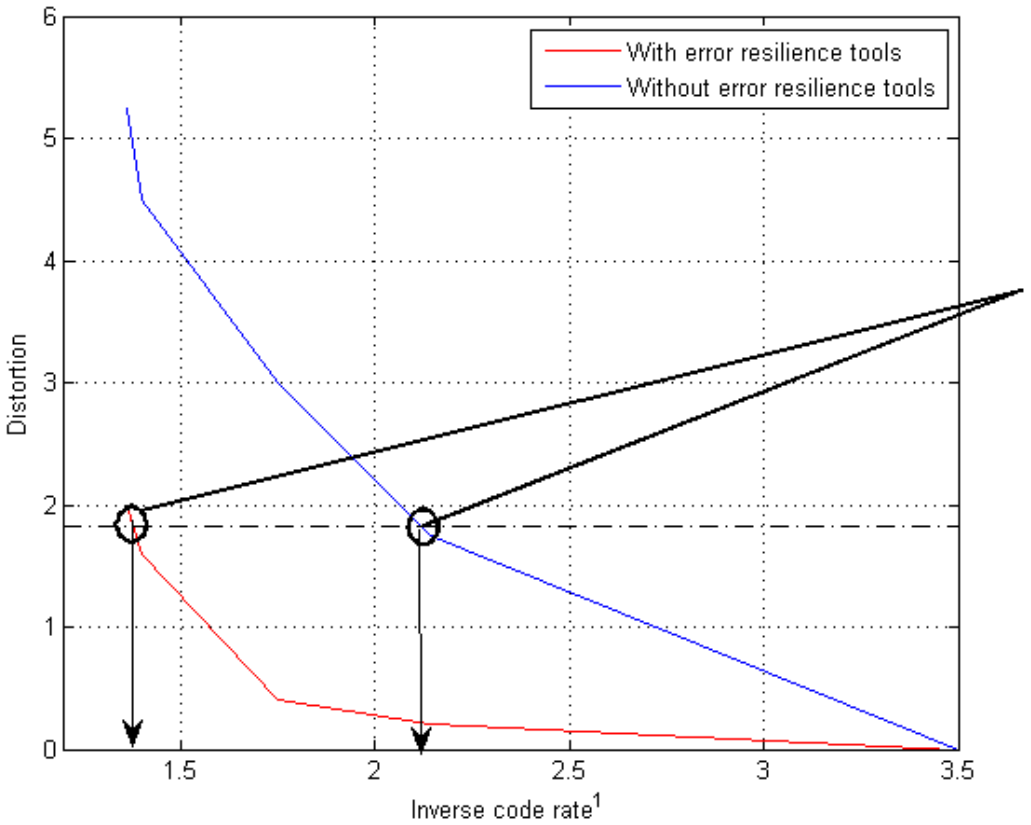
MPEG-4 error resilience tools: results



The amount of channel coding required to meet a maximum distortion threshold is lower when using error resilience tools

[1] The inverse code rate of a channel coding technique is defined as the ratio between the length of the codeword and the length of the original word.

Video examples

Original video
Without error resilience tools
With error resilience tools

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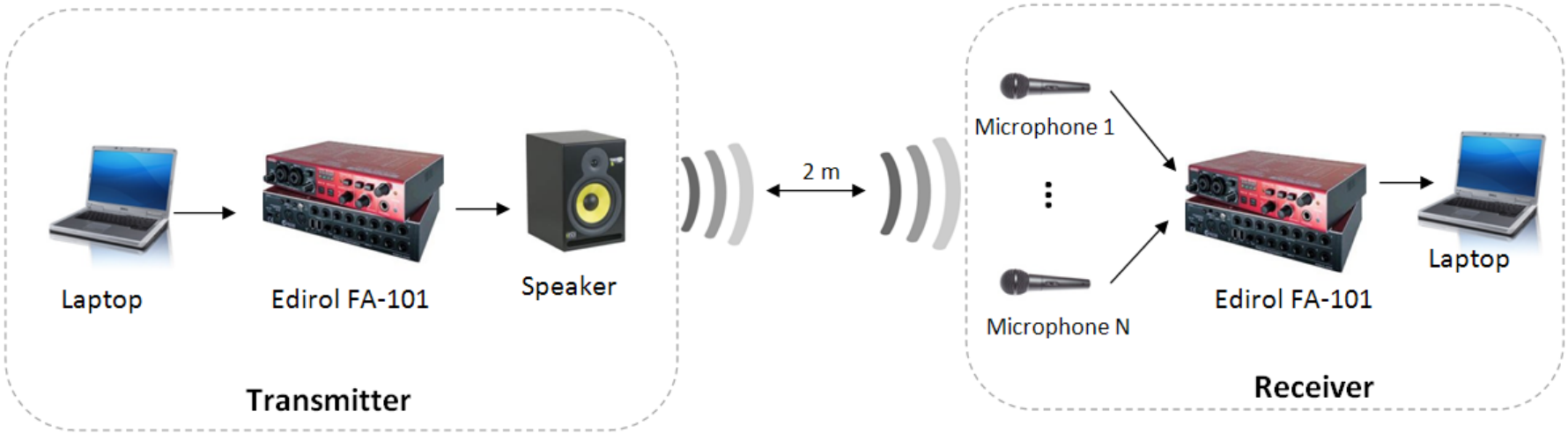
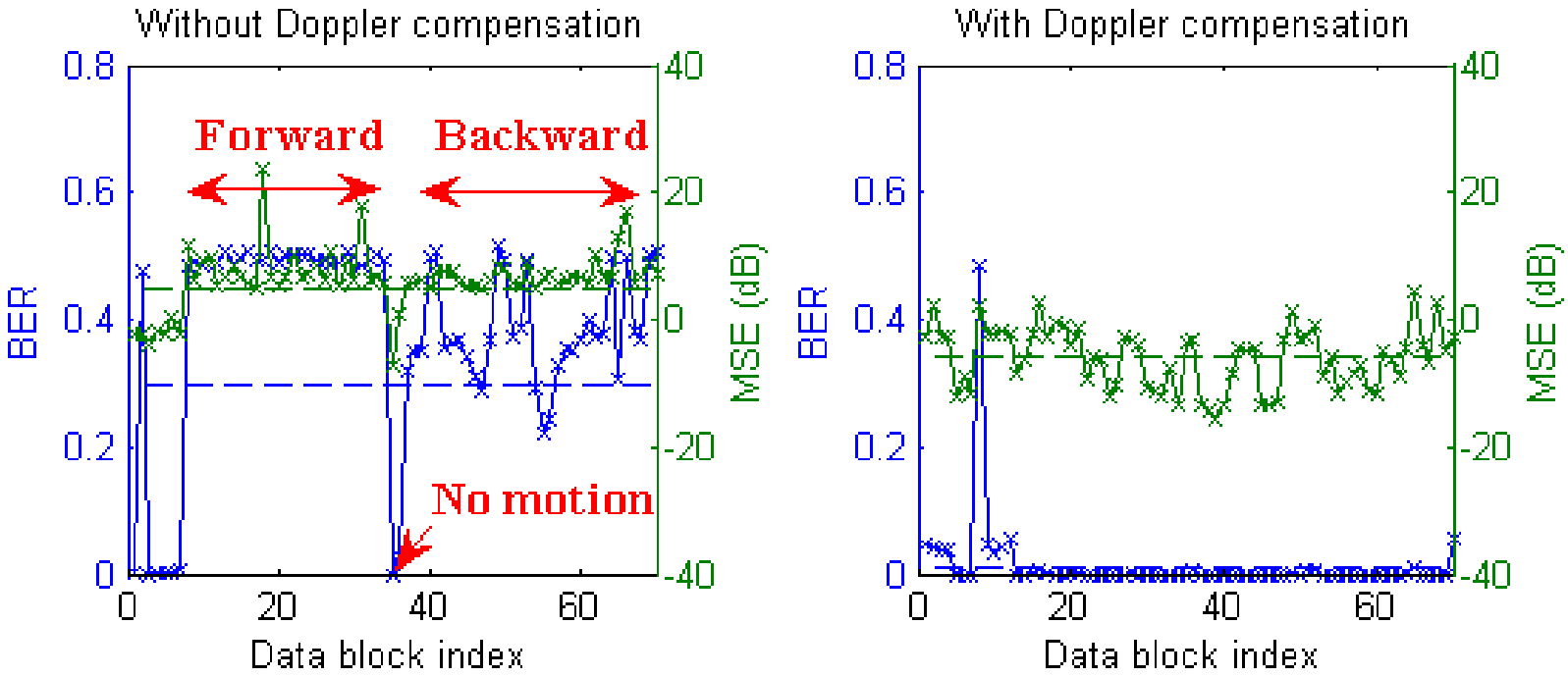
System deployment: in-air testbed



Experiment results



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Conclusions

- The combination of the Doppler compensation algorithm with differentially coherent detection provides **additional robustness against temporal motion variations**.
- The implementation of MPEG-4 error resilience tools allows us to **reduce the amount of channel coding**, thus increasing the available data rate while maintaining a good visual quality.

Applications

- Underwater defense applications, such as port security and hull inspections.
- Real-time environmental monitoring of marine life and reef.
- Supervisory control, surveillance, and intervention procedures in offshore oilfield environments.
- Deployment of AUV platforms in situations when ROVs are expensive to run.
- Open ocean exploration and sonar surveys.

END

Thank you

Questions?