Performance Evaluation of Filterbank Multi Carrier Systems in Vertical and Horizontal Underwater Acoustic Channels

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The Underwater Acoustic Channel

- The acoustic channel is regarded as the most reliable channel for underwater communications, due to the relatively low attenuation of sound in water.

- Despite this, propagation via the acoustic channel is severely limited by the available bandwidth, while also suffering from a large doppler and delay spread.

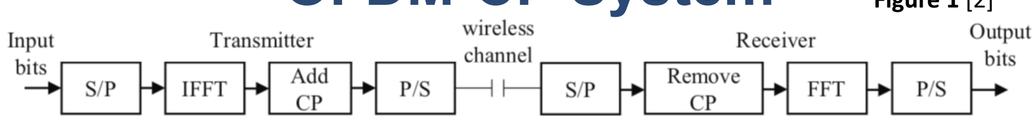
- As a result, the bit rates currently achieved in underwater communications are significantly lower than those achieved by LTE and 802.11b wifi.

Table 1 [1] Comparison of acoustic, EM and optical waves in seawater environments

	Acoustic	Electromagnetic	Optical
Nominal speed (m/s)	~ 1500	~ 33 333 333	~ 33 333 333
Power loss	relatively small	large	$\propto$ turbidity
Bandwidth	~ kHz	~ MHz	~ 10–150 MHz
Frequency band	~ kHz	~ MHz	~ 10^{14}–10^{15} Hz
Antenna size	~ 0.1 m	~ 0.5 m	~ 0.1 m
Effective range	~ km	~ 10 m	~ 10–100 m

OFDM-CP System

Figure 1 [2]



- OFDM-CP is currently the most used Multi Carrier technique due to its robustness against Inter Symbol Interference, along with its simple frequency domain equalization.

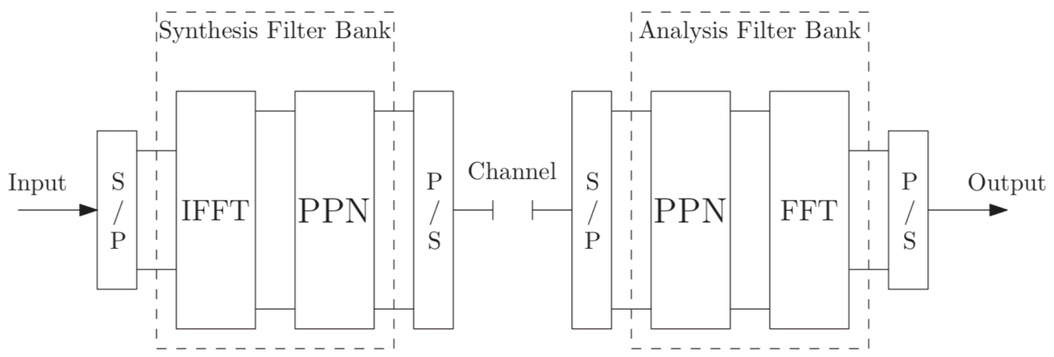
- The addition of a cyclic prefix reduces its spectral efficiency and limits the achievable bit rate.

Table 2 Theoretical Achievable Bit Rate*

System	Bandwidth (KHz)	No. of Subcarriers	Bit rate (kbps)	Spectral Efficiency %
OFDM-CP	115	4096	110.4	80
OFDM-OQAM	115	4096	138	100

OFDM-OQAM System

Figure 2 [3]



- OFDM-OQAM is an emerging new Multi Carrier Modulation technique, by which filter banks are added to the OFDM system, along with the real and imaginary part of each symbol being delayed by half a symbol duration.

- This allows for the removal of the cyclic prefix, thus increasing spectral efficiency and the achievable bit rate as shown in table 2.

BER Performance in UWA, AWGN & Rayleigh Channels

Figure 3*

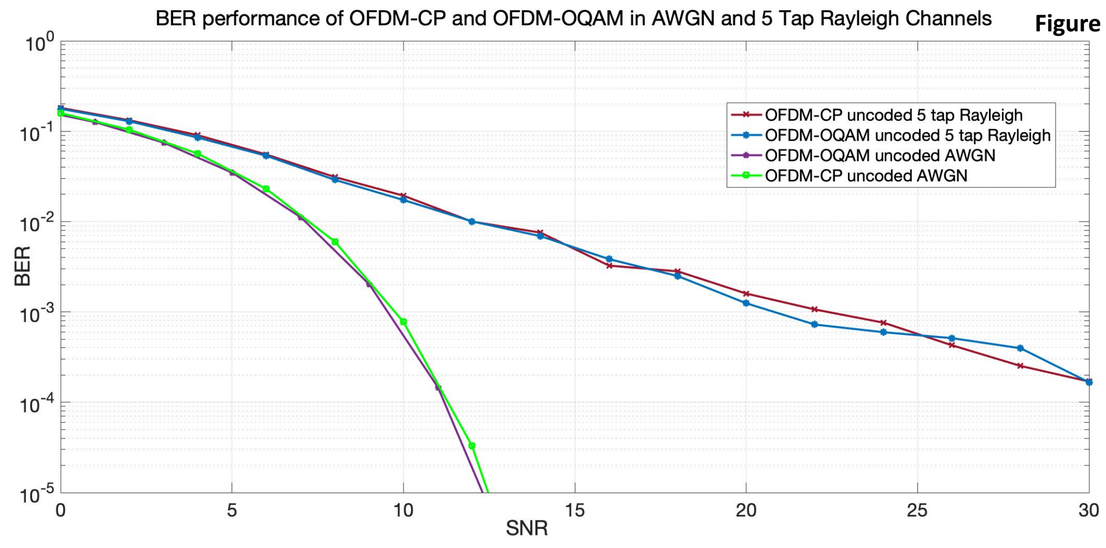
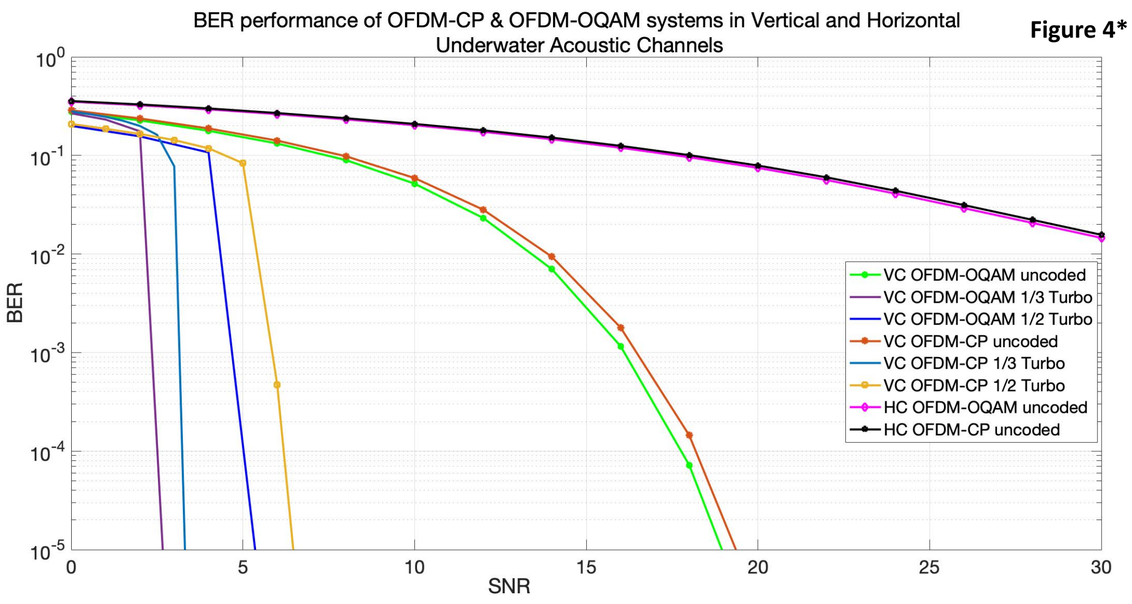


Figure 4*



- Figures 3 and 4 show that OFDM-OQAM systems exhibit similar BER performance to OFDM-CP systems in both AWGN, Rayleigh and UWA channels, even with the absence of a cyclic prefix.

- Powerful codes such as turbo codes can introduce a coding gain of up to 14dB at a BER of 10^{-3} in a vertical underwater channel.

- To conclude OFDM-OQAM offers an attractive improvement to achievable bit rates, however at the cost of increased equalization complexity.

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References

[1] S. Zhou and Z. Wang, *OFDM for underwater acoustic communications*. Chichester, West Sussex: Wiley, 2014, p. 2.

[2] Mohammud J. Bocus, Angela Doufexi, and Dimitris Agrafiotis , *"Performance Evaluation of Filterbank Multicarrier Systems in an Underwater Acoustic Channel "* , 2016, p. 2

[3] Qinwei He and Anke Schmeink, *"Comparison and evaluation between FBMC and OFDM systems"*, p. 1

* Table 2 assumes 16 QAM modulation, a coding rate of 0.3 and a CP of 25% of symbol length.
* In Figures 3 and 4 system parameters are set at 4096 sub carriers with 16 QAM modulation.