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Wavelet OFDM Performance in Frequency Selective Fading Channels

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Agenda

- WOFDM overview
- DWT-based implementation of WOFDM
- Daubechies wavelets in the time-frequency plane
- Simulation scenario
- Results & Conclusions

Objectives

- To evaluate the performance of the WOFDM transmission through FSF channels
- To highlight the influence of the wavelets "carriers" on the WOFDM performance
  - **Time-frequency localization of the carriers**
  - **Time & frequency characteristics of the channel**
  - **BER performance**

WOFDM Overview

- WOFDM= Wavelets based OFDM
- It can be seen as an orthogonal, "multi-carrier" modulation
- OFDM's complex exponentials replaced by wavelet "multiple carriers"
- WOFDM symbol can be expressed as:

j - scale

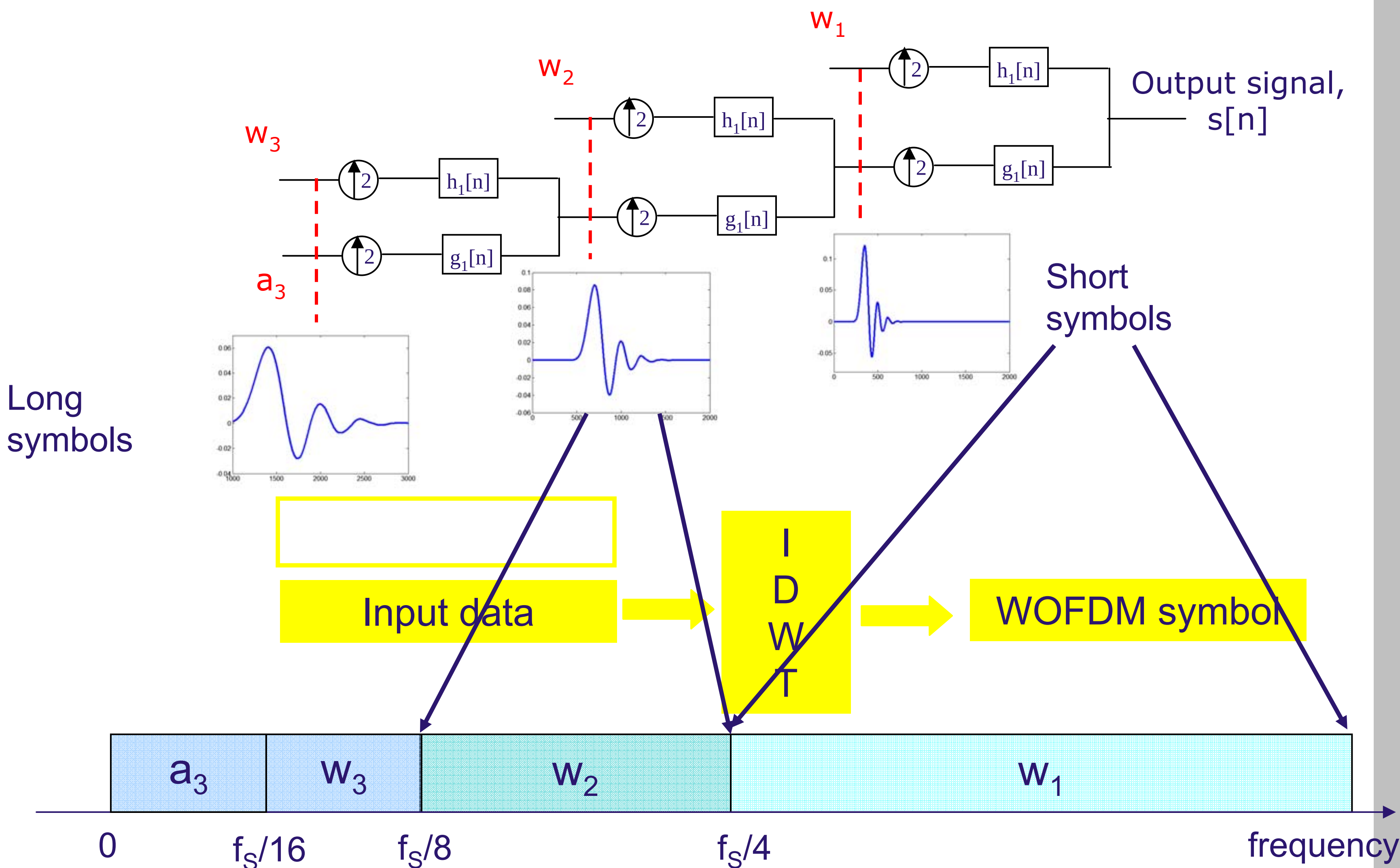
k - position

$$s(t) = \sum_{j=-J}^{0} \sum_{k} w_{j,k} \psi_j(t-k) + \sum_{k} a_{-J,k} \varphi_{-J}(t-k) \quad (1)$$

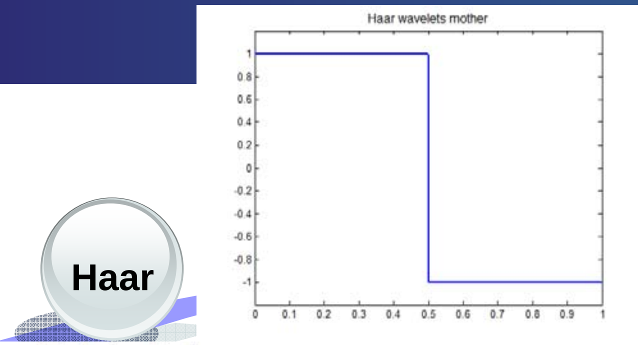
- $\{\psi_j(t-k)\}$ defines an ortogonal family of carriers
- Data symbols to be sent may be interpreted as a sequence of approximation ($a_{J,k}$) and wavelet coefficients ($w_{j,k}$)
- Numerical implementation (Mallat's IDWT)

DWT based implementation

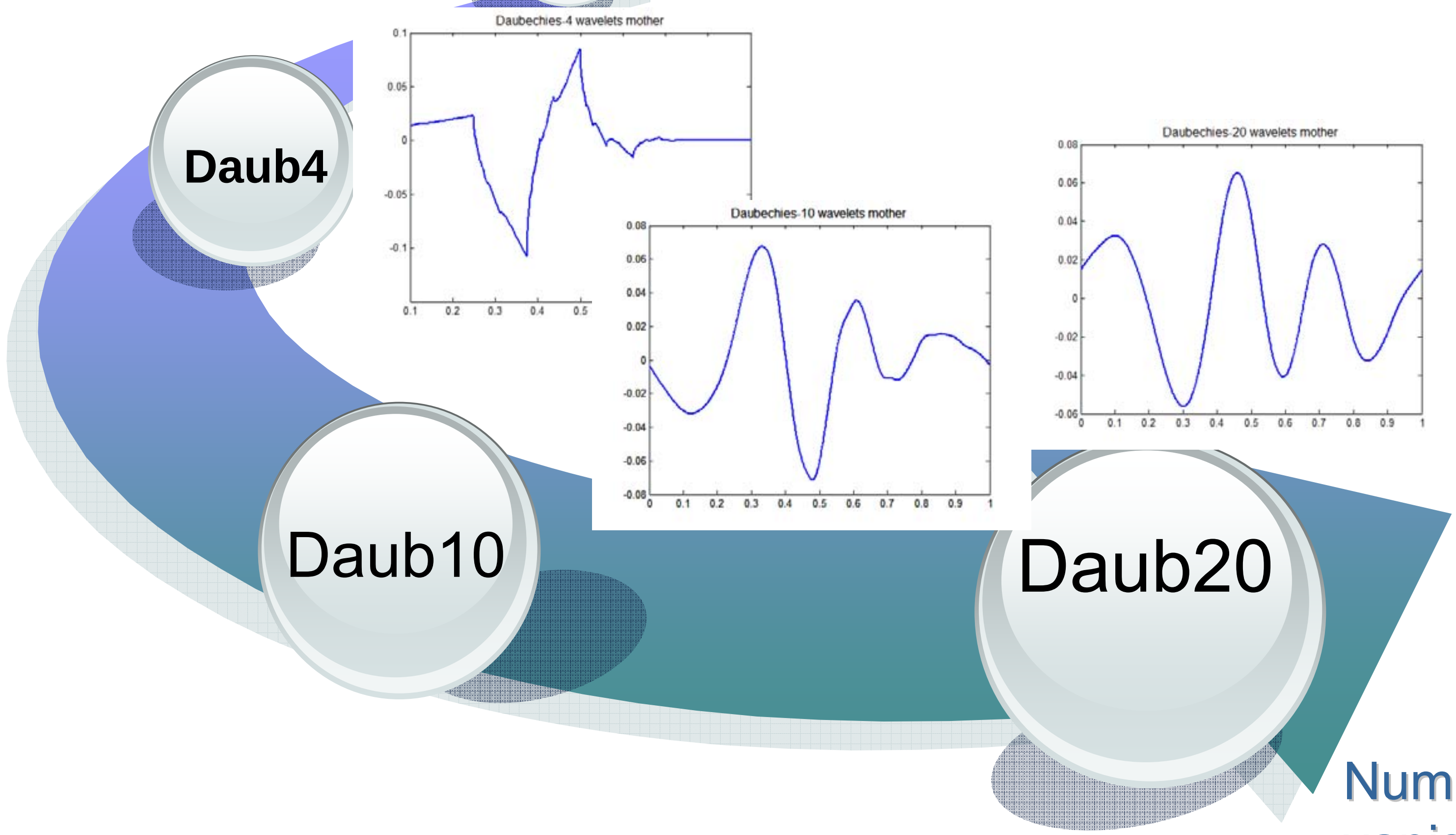
Fig. 1: IDWT (Mallat) based implementation of WOFDM.



Daubechies wavelets in the time-frequency plane



- Excellent time localization
- Very poor frequency localization



- Good frequency localization
- Poor time localization

Number of vanisihing moments

Goals

T-F localization of the carriers

T-F properties of the channel

BER performance

Time the frequency content-function of the number of vanishing moments

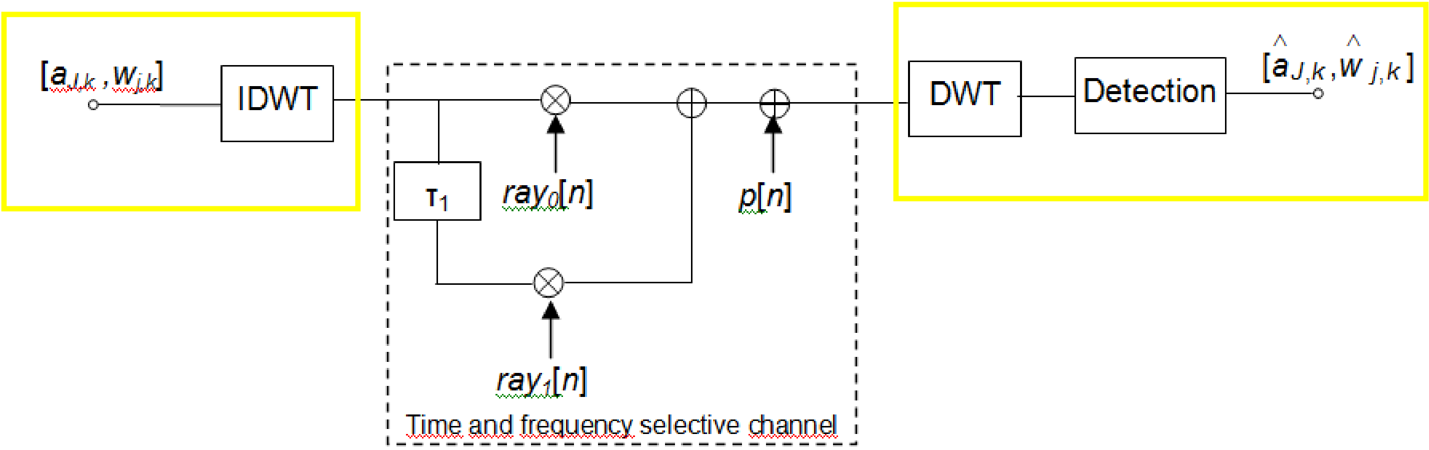
Time and frequency response-depends on the power/delay of the second path and on the Doppler shift

T-F properties of the wavelet carriers adapted to the T-F properties of the channel

Background: in flat, time variant channels, wavelets that have good time localization (e.g., Haar) lead to the best results

Focus on transmitter / receiver

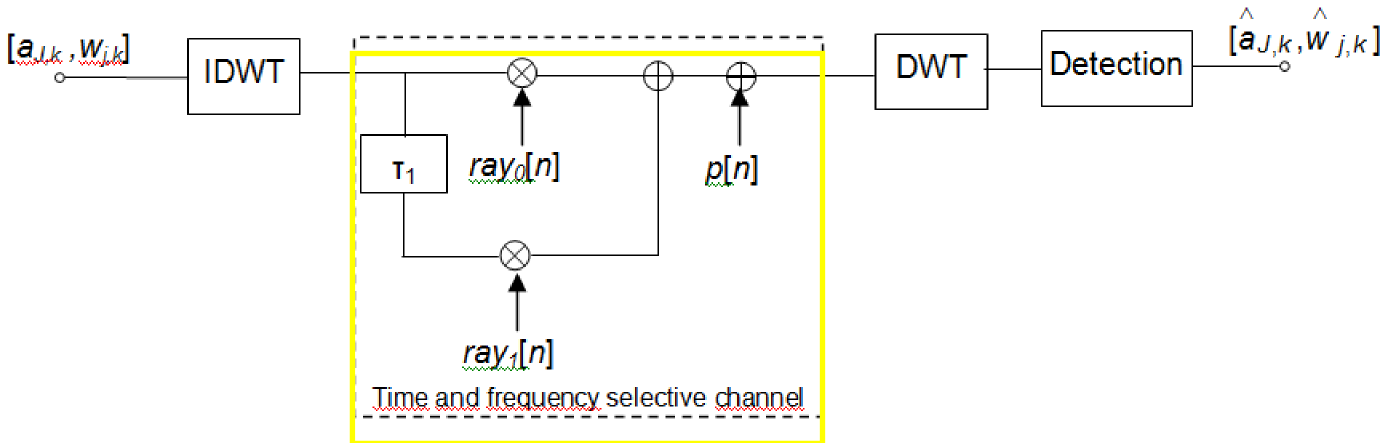
Fig. 2: Simulation scheme for the WOFDM transmission in a two-ray FSF channel.



- Equally likely bipolar symbols (BPSK)
- Daubechies wavelets tested in the IDWT modulator
  - **4 iterations (4 transmission scales)**
- BER performance is computed for the overall block, as well as on a per-scale basis
  - **Lower transmission scales stronger affected by ISI**
  - **Higher transmission scales stronger affected by Doppler**

Focus on the channel

Fig. 2: Simulation scheme for the WOFDM transmission in a two-ray FSF channel.



- Two ray channel
- Both paths are random (fluctuant)
- Time variability
  - $ray_k[n]$: Rayleigh pdf, Jakes'PSD, f_m: maximum normalized Doppler shift
- Frequency selectivity
  - τ_1: relative delay of the second path
  - P_1: the relative power of the delayed path
  - Multipath delay spread:

$$\sigma_\tau = \sqrt{\overline{\tau^2} - (\bar{\tau})^2} \quad (2)$$

Overall BER performance

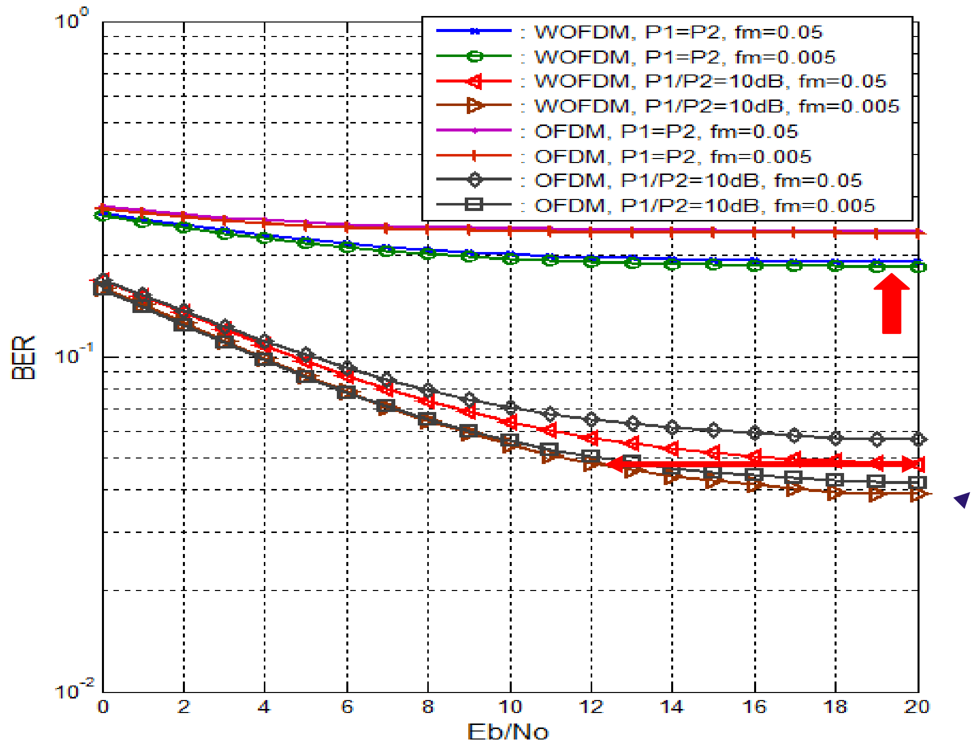


Fig. 3: Overall BER performance of a WOFDM/OFDM transmission using Daubechies-8, in a two ray FSF channel, τ1=1.

- **Poor BER results because: NO equalization, NO channel coding, NO compensation for the Doppler shift**
- **No difference made by the Doppler shift when the ISI component is strong**
  - A difference only occurs when P_0/P_1=10
- **WOFDM slightly better than OFDM**

Haar vs Daub20: some time, frequency and scale considerations

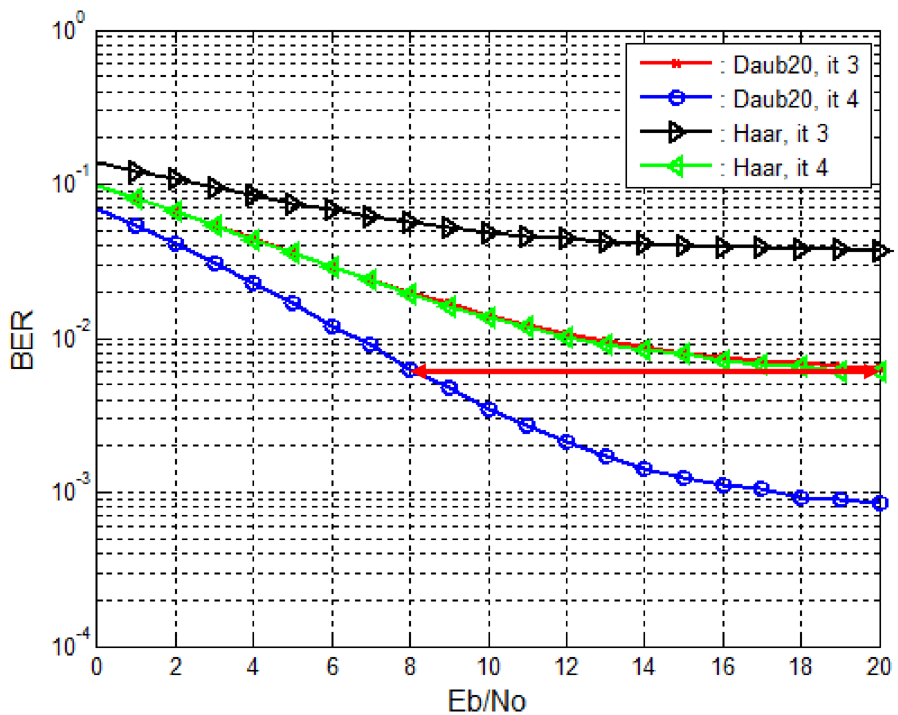


Fig. 4: Haar vs Daubechies 20: the BER performance at the third and the fourth transmission scale, *P1*=*P2*, *fm*=0.005.

- **Some transmission scales are stronger affected by ISI than others**
  - No BER difference among different wavelets
- **When ISI is less critical, wavelets with good frequency localization achieve better results**
  - The result is the opposite of the flat fading channel case
- **At the same scale, Daub20 performs much better than Haar**

BER performance (Daubechies wavelets)

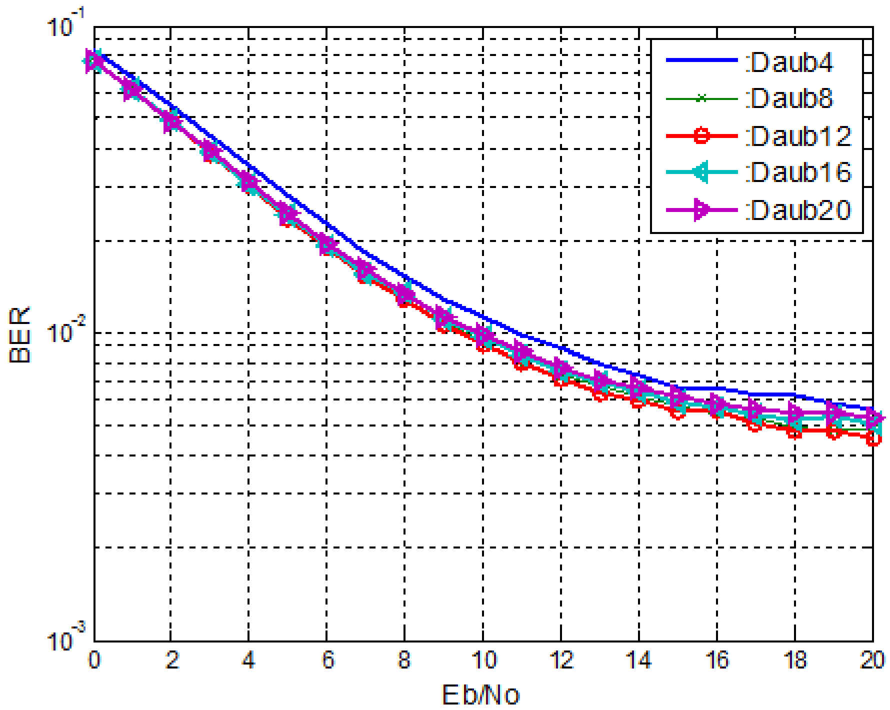


Fig. 5: BER performance at the fourth scale of a WOFDM transmission, for all the Daubechies wavelets, *P1=P2, fm*=0.05.

- **When ISI and Doppler are “balanced”, wavelets that achieve good T-F compromise lead to better results**
  - Best result: Daubechies-12, worst result: Daubechies-4
  - at the fourth scale, we have the strongest impact of Doppler, and the less important ISI influence

Conclusions

- For the considered channel model, ISI strongly degrades the BER
  - **No overall BER difference among the tested wavelets, at the scales dramatically impacted**
  - **Interesting effects may be however shown on the transmission scales**
- At some scales, less distorted by ISI, a good frequency localization of the carriers transforms into an advantage
  - **In some particular cases, wavelets with a good time-frequency localization led to the best results**

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