Introduction to and some results on DS-UWB, multiband UWB, and multiband OFDM

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Ultrawaves

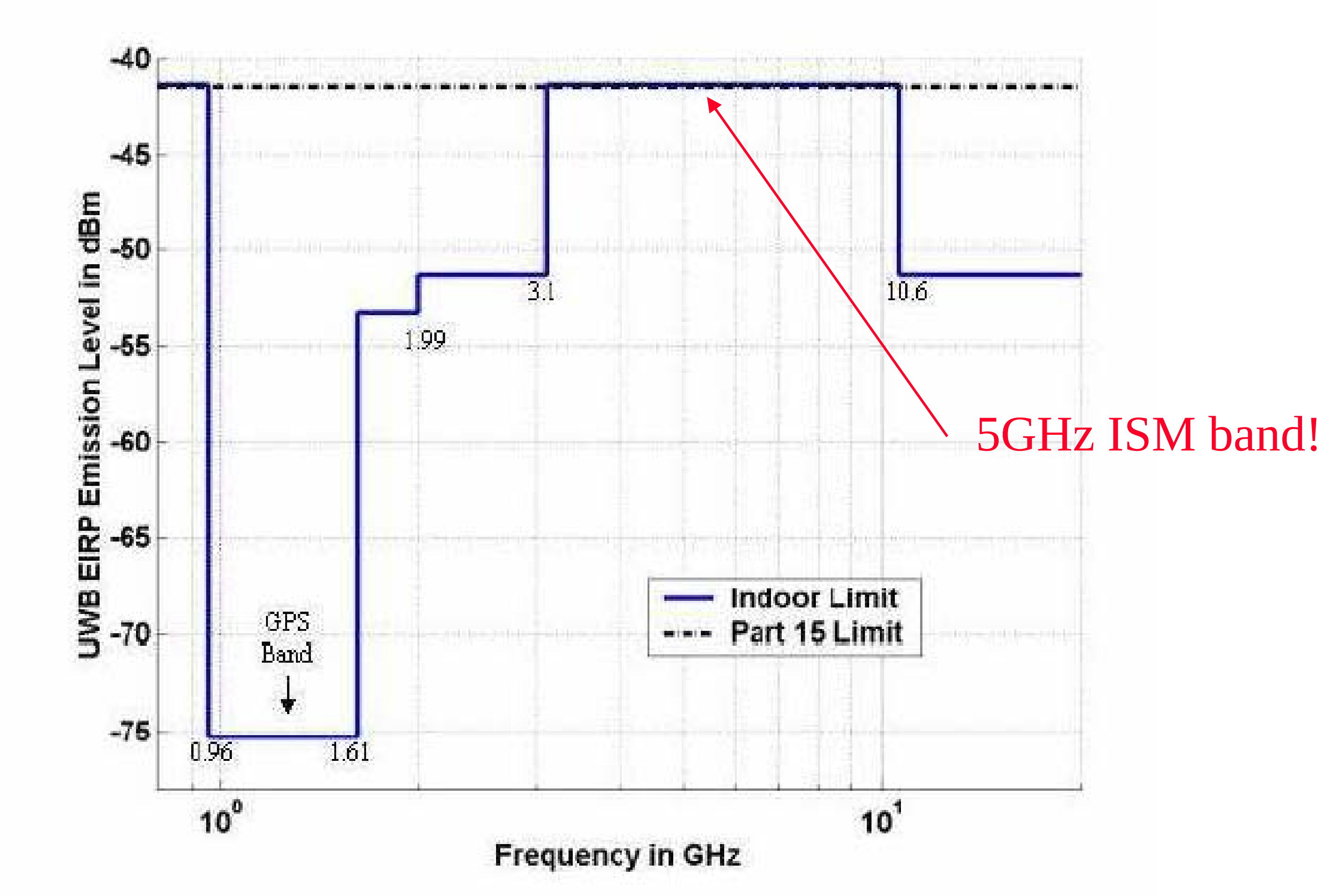
Outline

- UWB Background
- IEEE UWB Channel Model
- Single-Band Impulse Radio
- Multiband Impulse Radio
- Multiband-OFDM
- Discussion and Conclusions

UWB Background

- A signal is UWB when the bandwidth is larger than 0.25 times the carrier freq.
- FCC requires the -10 dB bandwidth to be at least 500 MHz
- FCC has defined a spectrum mask
  - -41.3 dBm/MHz is the maximum EIRP between 3.1 GHz to 10.6 GHz (556 μW in the whole band, 111 μW in 1.5 GHz)

FCC spectrum mask



Single-band vs multiband

- **Single-band**: using the whole available spectrum
  - transmitting very short pulses (impulse radio)
- **Multiband**: dividing the available spectrum into several bands, each having a minimum of 500 MHz of bandwidth, to comply with the FCC requirements
  - Introduces orthogonality in the freq. domain
  - Impulse radio with longer pulses in each band
  - OFDM in each band

IEEE UWB Channel Model

- Based on the Saleh-Valenzuela channel model where multipath components arrive in clusters.

$$c(t) = \sum_{l \geq 0} \sum_{k \geq 0} \alpha_{k,l} \delta(t - T_l - \tau_{k,l})$$

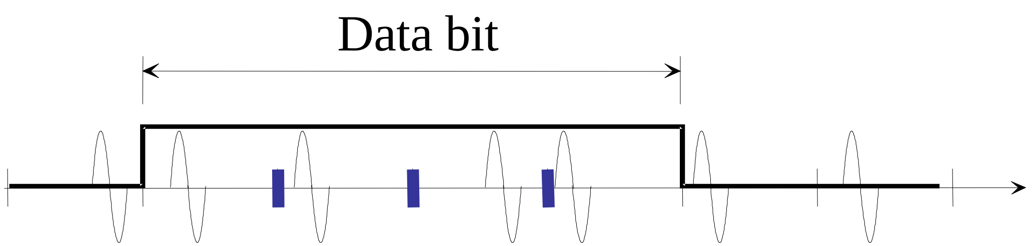
- T_l arrival of cluster l, $\tau_{k,l}$ arrival of ray k within cluster l
- Shadowing with $X=10^{\text{normal}(\mu=0,\sigma=3\text{ dB})}$

$$h(t) = Xc(t)$$

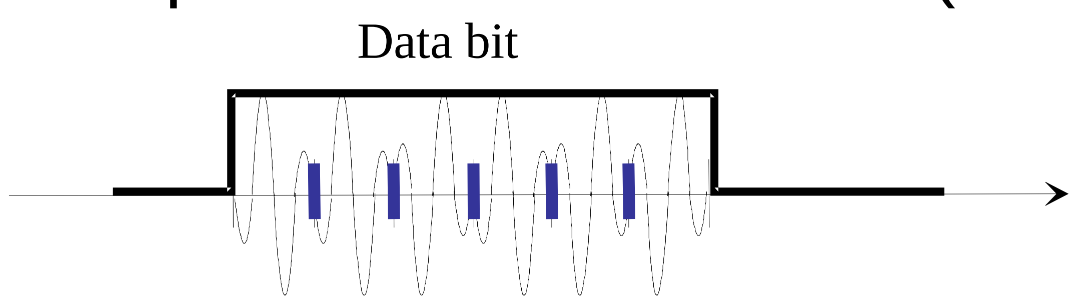
- Four models
  - CM1: LOS 0-4 meter, (RMS delay spread 5 ns)
  - CM2: NLOS 0-4 meter, (RMS delay spread 8 ns)
  - CM3: NLOS 4-10 meter, (RMS delay spread 14 ns)
  - CM4: NLOS RMS delay spread 25 ns
- Block fading models!

Single-band TH-UWB and DS-UWB Impulse Radio

- Time-Hopping Ultra-wideband (TH-UWB)



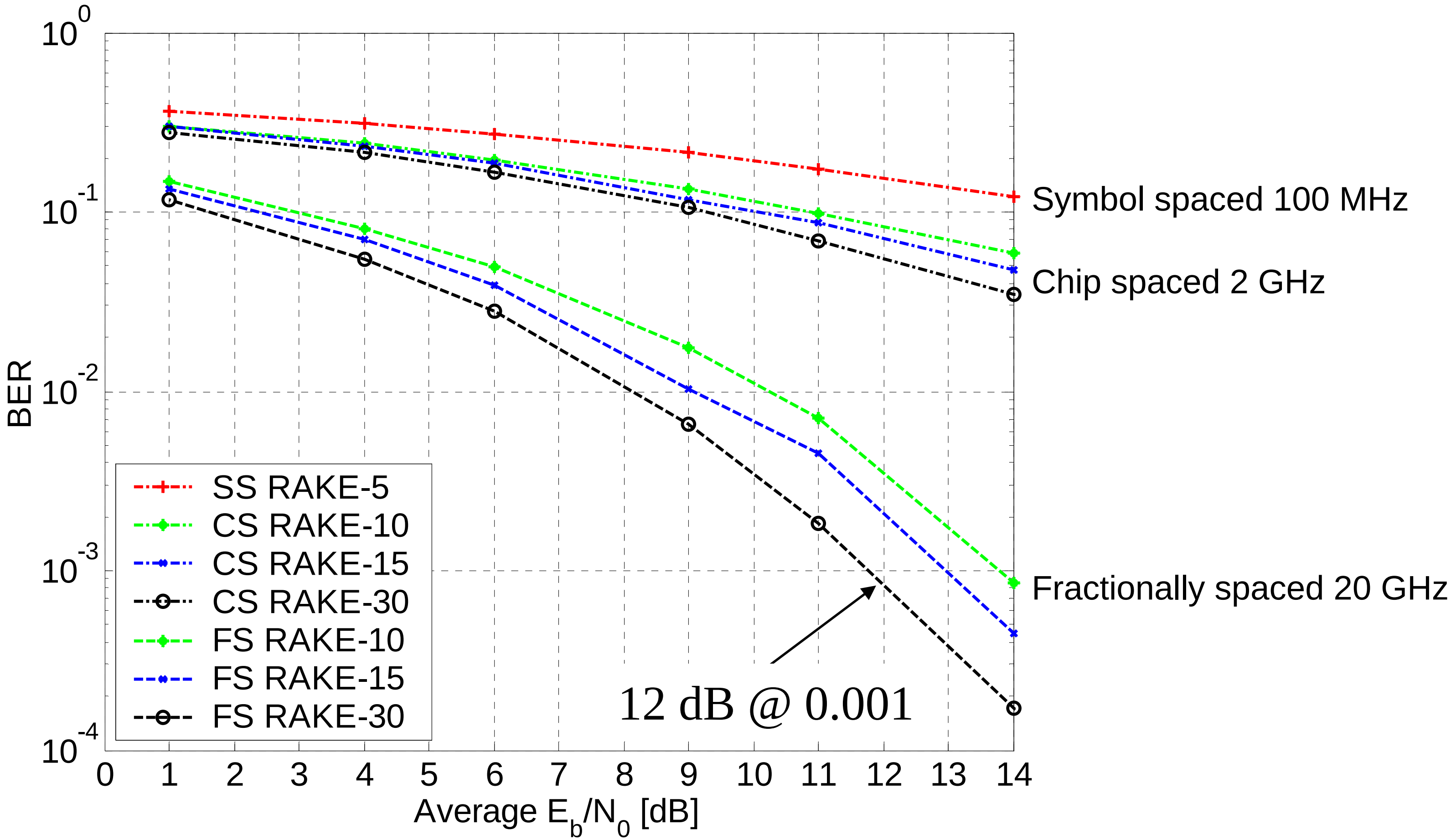
- Direct-Sequence Ultra-wideband (DS-UWB)



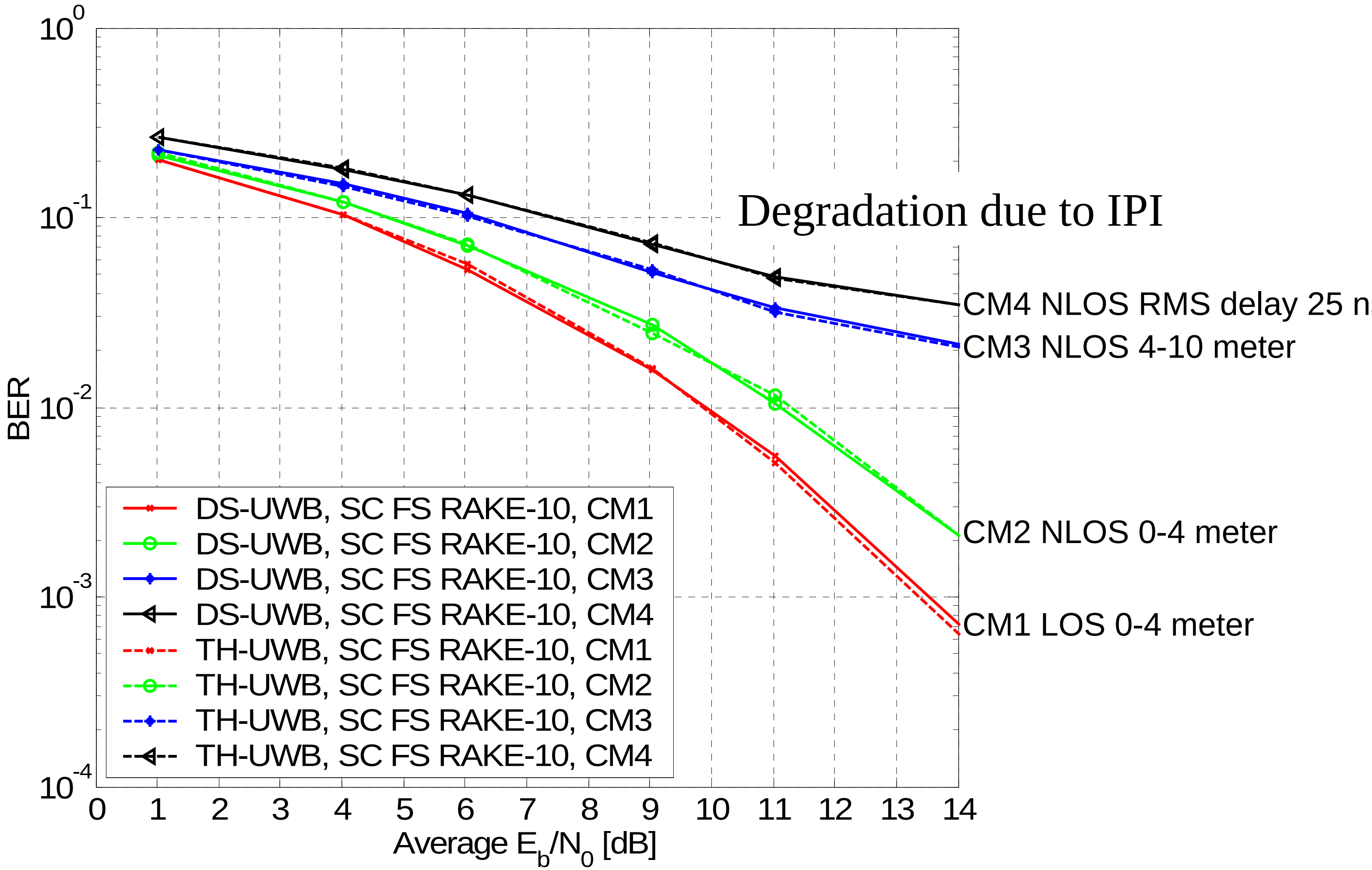
Numerical Results

- IEEE UWB model with shadowing
- 2.5 to 6.8 GHz pulse with a duration of 0.5 ns
- Processing gain is 20 or 13 dB
- Data rate **100 Mbps**
- Channel estimation included
- Fractionally and chip spaced Rake receiver

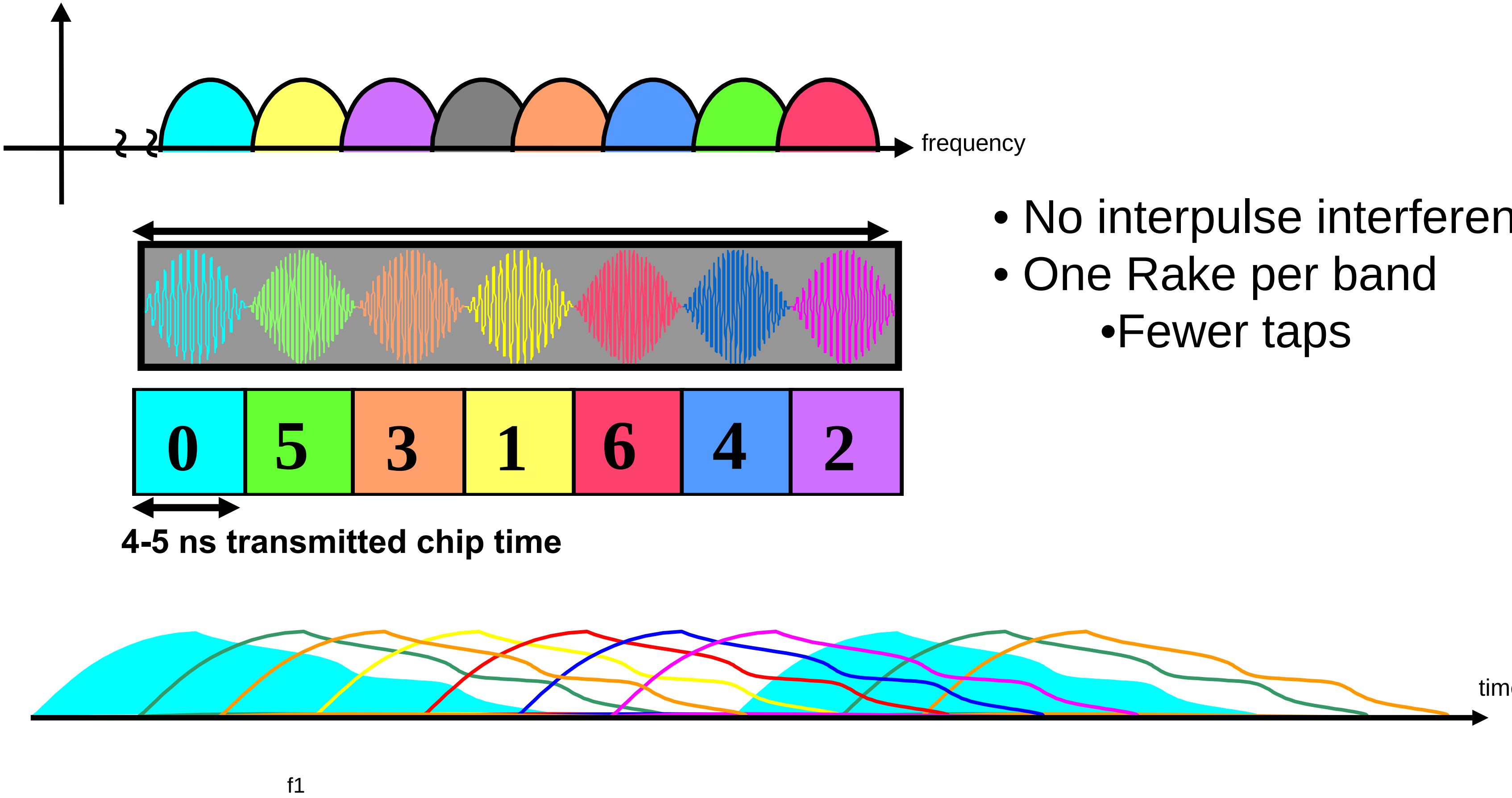
Symbol-, chip- and fractionally spaced Rake with perfect channel estimate for DS-UWB on CM1 with shadowing



TH-UWB and DS-UWB with fractionally spaced Rake and successive channel estimation algorithm



Multiband MB-UWB Impulse Radio

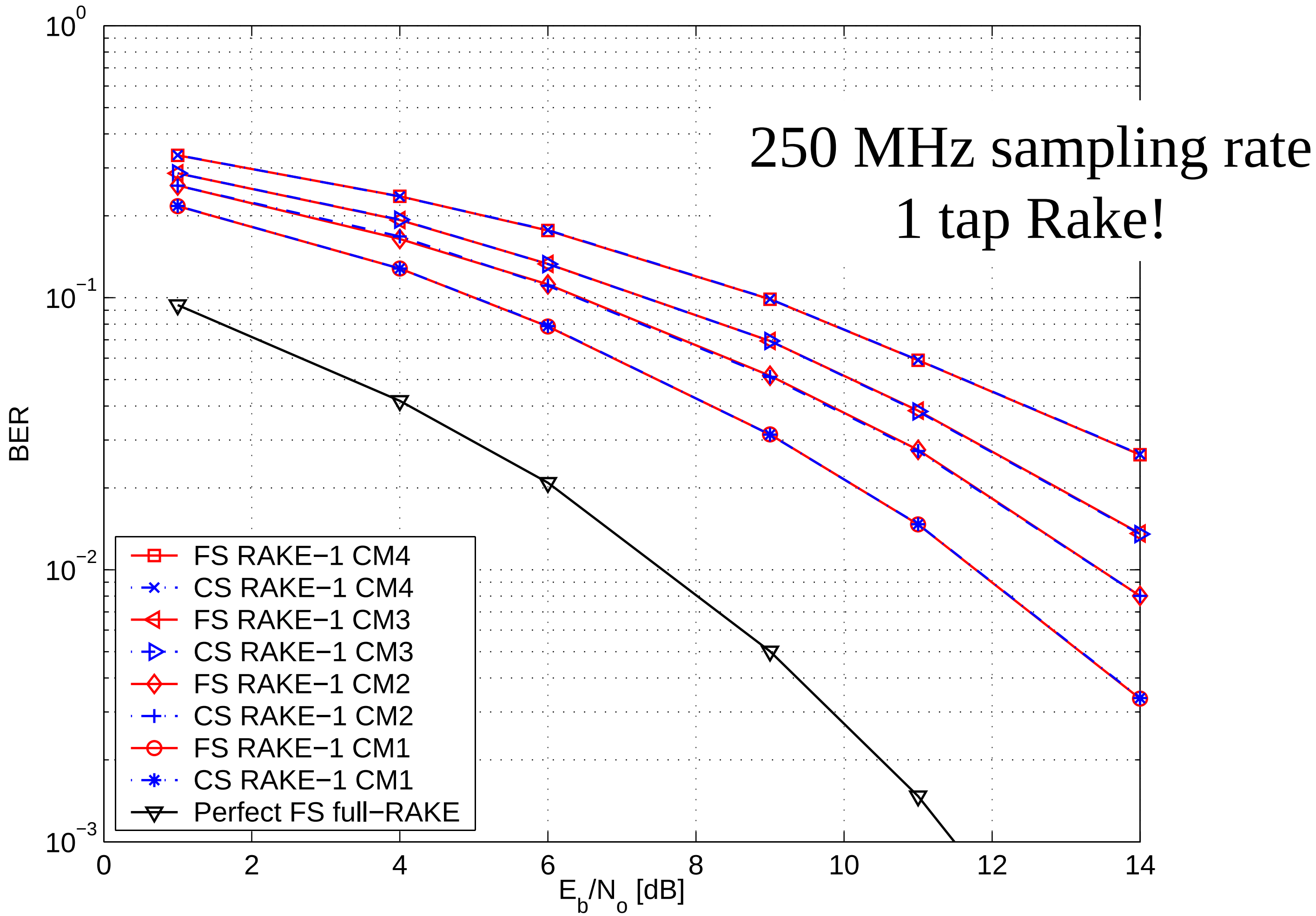


- No interpulse interference
- One Rake per band
  - Fewer taps

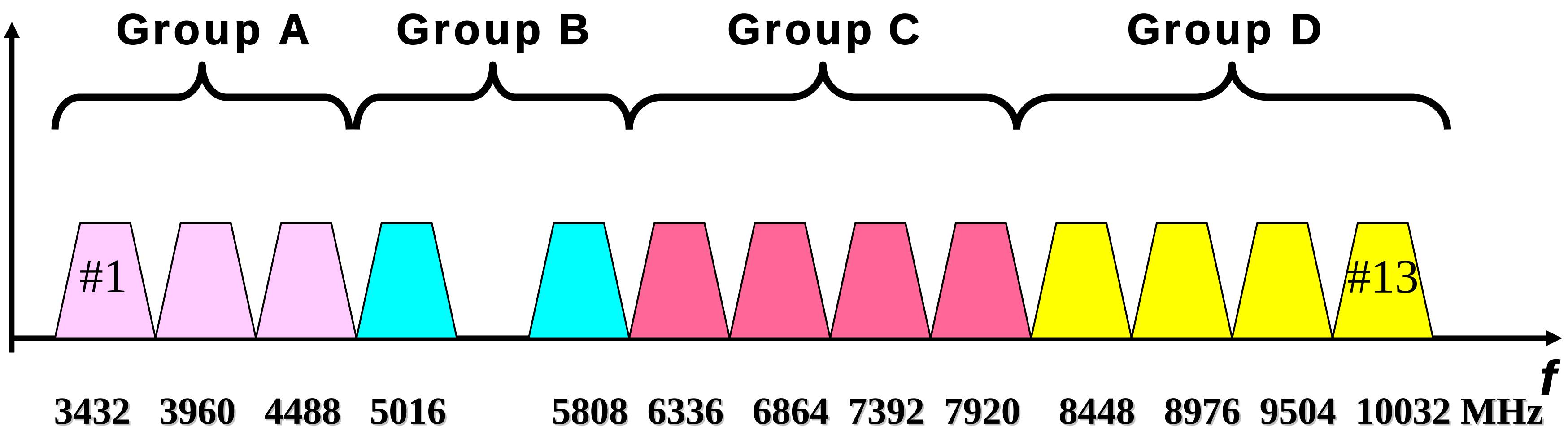
Numerical Results

- IEEE UWB model with shadowing
- 6 Bands with between 3.1 and 6.1 GHz
- 4 ns pulse duration and 24 ns pulse repetition
- Pulse rate 250 Mpulses/s
- Repetition code 1/2
- Processing gain 12
- Data rate **125 Mbps**
- Sliding window channel estimation
- Fractionally and chip spaced Rake receiver

Multiband-UWB

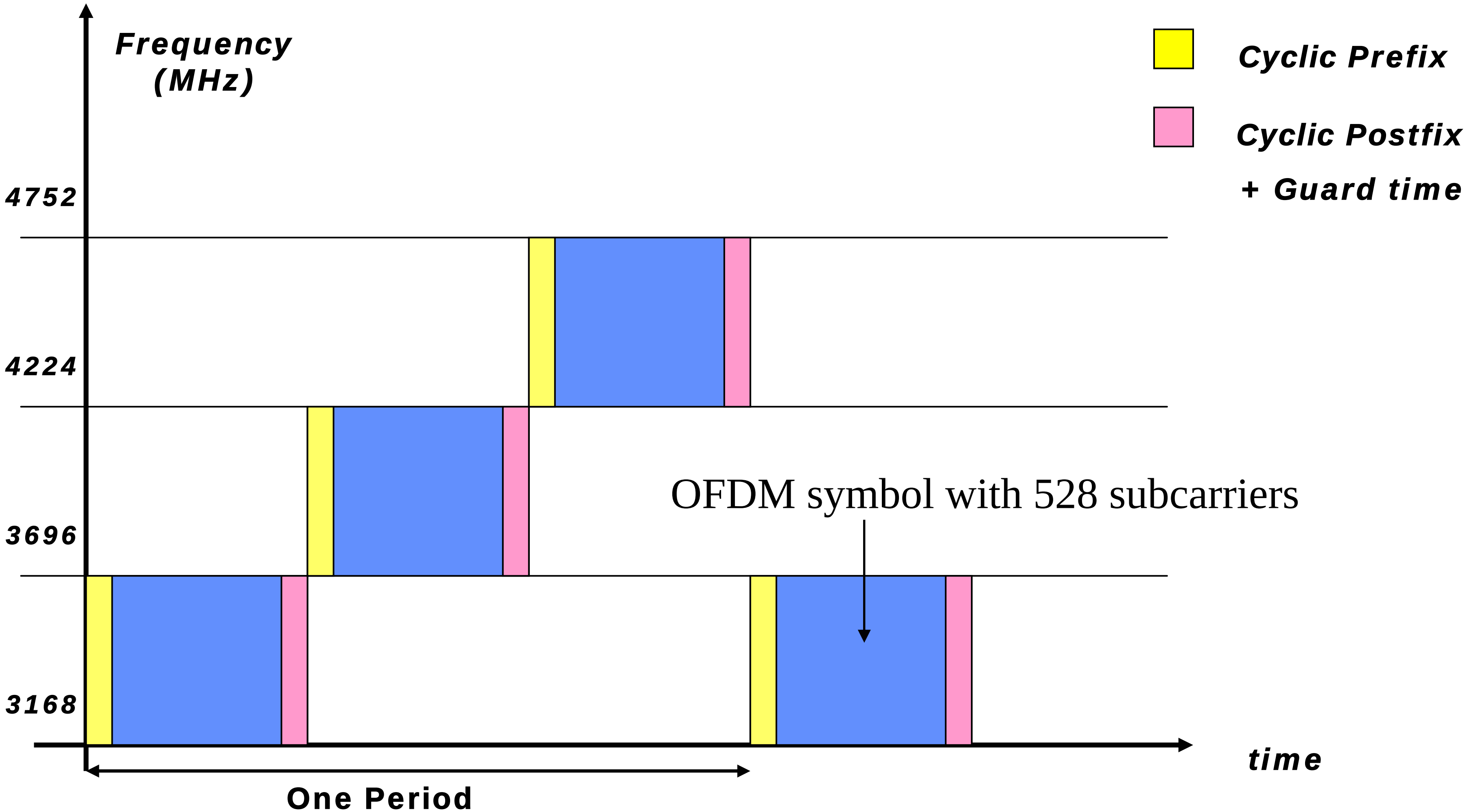


IEEE multiband OFDM approach



- Group A: 3.1-4.9 GHz. Assigned for 1st generation devices
- Group B: 4.9-6 GHz. Designated for future use
- Group C: 6-8.1 GHz. Intended for devices with improved SOP (Simultaneously operating piconets) performance
- Group D: 8.1-10.6 GHz. Designated for future use

Multiband OFDM



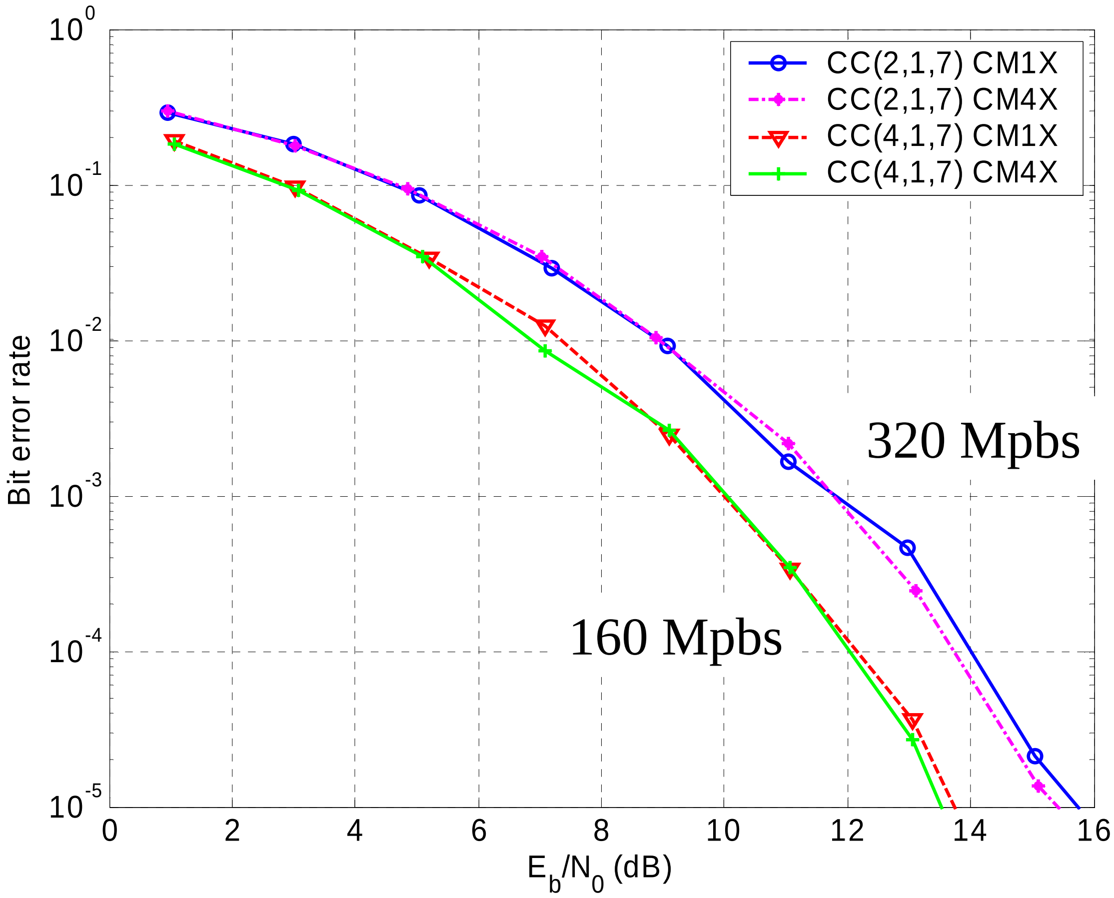
OFDM system data

Parameter	Value
fs: sampling frequency	528 MHz
N_{DS}: # of data subcarriers	100
N_{PS}: # of pilot subcarriers	12
N_{TS}: total # of subcarriers used	112
Δ_F: subcarrier frequency spacing	4.125 MHz (= 528MHz/128)
T_{FFT}: FFT/IFFT period	242.424 ns (1/4.125 MHz)
T_{GI}: guard interval duration (prefix+postfix duration)	60.6 ns (= 32 samples/528 MHz)
T_{GT}: guard time	9.47 ns (= 5 samples/528 MHz)
T_{SYM}: total OFDM symbol duration	312.5 ns ($T_{SYM} = T_{FFT} + T_{GI} + T_{GT}$)
Channel bit rate	640 Mbps

Numerical Results

- IEEE UWB model with shadowing
- 3 bands of 528 MHz between 3.1- 4.6 GHz
- Convolutional codes with rate 1/2 and 1/4 with constraint length equal to 7
  - Channel coding required to obtain diversity
- Information data rate **320 and 160 Mbps**
- Block interleaver
- *Perfect channel estimator*

Numerical Result of Coded OFDM



Summary and Conclusions

- Three systems
  - DS-UWB system: 10 Rake fingers, sampling frequency of 20 GHz, data rate 100 Mbps, 2.8-6.8 GHz
  - MB-UWB: one Rake finger per band, sampling frequency 0.25 GHz, data rate 125 Mbps, 6 bands, 3.1-6.1 GHz
  - MB-OFDM: data rate 320 and 160 Mbps, sampling frequency 528 MHz, 3 bands, 3.1-4.6 GHz
  - *Results should be compated with care!*
- MB-UWB performs almost equally well as DS-UWB and TH-UWB with much fewer Rake taps
- MB-OFDM has much better performance than the other two
- The impulse radio systems might improve with more advanced channel coding (only repetition coding used now)
- *MB-OFDM seems to be a very promising UWB solution*

Thank you!

Any questions or comments?