On Partially Overlapping Coexistence for Dynamic Spectrum Access in Cognitive Radio

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Outline

1. Introduction
2. Aim of the work
3. System Models
4. Simulation Results
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Problem
Increasing demand of bandwidth to support new services with limited spectrum resources.

Solution
Cognitive Radio (CR) technology.

Approach 1
Cognitive Users (CUs) access Primary Users (PUs) spectrum holes (temporally or spatially).

Approach 2
Spectral sculpting of CUs to allow partial frequency overlap (coexistence) with PUs.
Attractive modulation candidate for CUs: OFDM due to its flexibility and adaptivity.

Partially overlapping coexistence concept.
Aim of the work

- Study the coexistence of CUs (OFDM) and PUs (NB and OFDM, respectively).
- Find the minimum frequency separation between coexisting systems to meet a target BER.
- Investigate techniques (windowing, nulling subcarriers) to increase minimum frequency separation.
- Explore the effect of windowing and nulling subcarriers on the OFDM CU PAPR and spectral efficiency.
OFDM (CU & PU)

$$s_{\text{OFDM}}(t) = \frac{1}{\sqrt{T_o}} \sum_{n=-\infty}^{\infty} \sum_{k \in \Omega} a^n_k e^{i2\pi f_k(t-nT_o)} w(t - nT_o)$$

NB PU

$$s_{\text{NB}}(t) = \sum_{k=-\infty}^{\infty} b_k p(t - kT - \xi) e^{i2\pi f_c t}$$
Simulation Setup

OFDM
- $BW_{OFDM} = 1.25$ MHz
- $N = 128$
- $\Delta F = 9.7656$ kHz
- $T_u = 102.4$ $\mu$sec
- $T_{cp} = 25.6$ $\mu$sec
- Modulation: QPSK
- Channel: AWGN - frequency selective channel

NB
- $BW_{NB} = 15$ kHz
- Roll-off factor, $\alpha = 0.35$
- Modulation: QPSK
- Channel: AWGN - frequency flat channel

\[
F_n = \frac{f_c - 0.5 \cdot BW_{OFDM}}{\Delta F}
\]
First Coexistence Scenario

- OFDM - NB case.
AWGN channel

NB PU BER as a function of $F_n$ in AWGN channel at $\frac{E_b}{N_o} = 10 \, dB$. 
OFDM CU BER as a function of $F_n$ in AWGN channel at $\frac{E_b}{N_0} = 10 \, dB$. 
Fading channel

NB PU BER as a function of SIR in fading channel at $\frac{E_b}{N_0} = 35\, dB$. 
Second Coexistence Scenario

- OFDM - OFDM case.
AWGN channel

OFDM PU BER as a function of $F_n$ in AWGN channel at $\frac{E_b}{N_0} = 10$ dB.
OFDM PU BER as a function of OFDM CU number of subcarriers in AWGN channel at SIR = 0 dB and $\frac{E_b}{N_0} = 10$ dB.
Windowing

NB PU BER as a function of the raised cosine window roll-off factor $\beta$ in AWGN channel at SIR = 0 dB and $\frac{E_b}{N_0} = 10 \, dB$. 

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Nulling

NB PU BER as a function of the OFDM CU number of nulled subcarriers in AWGN channel at SIR = 0 dB and $\frac{E_b}{N_0} = 10 \text{ dB}$.
Effect of windowing and nulling on OFDM CU PAPR

OFDM CU PAPR for $\beta = 0.15$ and 3 nulled subcarriers, respectively.
Effect of windowing and nulling on spectral efficiency

\[ \zeta = \frac{mN_u/(T_s(1 + \beta))}{N\Delta F} \]

**Windowing**

\[
\begin{align*}
\beta &= 0.15 \\
N_u &= 128
\end{align*}
\]  \[\Rightarrow \zeta = 2.7826 \text{ (bits/sec)/Hz} \]

**Nulling**

\[
\begin{align*}
\beta &= 0 \\
N_u &= 125
\end{align*}
\]  \[\Rightarrow \zeta = 3.125 \text{ (bits/sec)/Hz} \]
Coexistence between OFDM CU, and NB PU and OFDM PU systems is considered.

Minimum frequency separation to meet a target BER is found to be a function of SIR and channel conditions.

Minimum frequency separation can be improved by windowing or nulling subcarriers; however, this reduces spectral efficiency.

Balancing trade-offs between spectral efficiency and minimum frequency separation for the coexistence scenarios.
Questions?