Project	**IEEE 802.20 Working Group on Mobile Broadband Wireless Access** **<http://grouper.ieee.org/groups/802/20/>**
Title	**Partial proposal to support flexible, spectrally efficient multi-carrier mode -- Presentation**
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Re:	IEEE 802.20 Call for Proposal
Abstract	This document proposes the support of reduced channel spacing to improve the spectral efficiency of Mobile Broadband Wireless Access Systems in the multicarrier deployment mode.
Purpose	For consideration and adoption as a feature supported by 802.20 standard
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Partial Proposal to Support Flexible, Spectrally Efficient Multi-Carrier Mode

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March 13, 2007

Introduction

- Support of spectrally efficient Multi-Carrier Mode
- Previous Letter Ballot 1 and 2 Comments
- Initial Simulation Results discussed in Jan ’07 meeting
- Additional simulation scenarios and results included in the current proposal
- Specific changes to the current standard draft included in the proposal for consideration

Problem Description

- In a conventional Multi-Carrier deployment scenario, Guard bands are used to:
  - Ensure the regulatory requirements on out-of-band emissions are met
  - Performance of adjacent channels (carrier) is not degraded significantly by the interference caused by the out-of-band emissions

- Simulation studies [2] found that the requirements on the number of quasi-guard subcarriers (channel spacing) between adjacent channels in a multi-carrier OFDM/A system is much less stringent than in the conventional system
  - Spectral efficiency in the multi-carrier mode can be improved by using a smaller channel spacing
  - Number of Quasi-Guard subcarriers need not be the same as Guard subcarriers

Multi-Carrier Mode Supported by Current 802.20 Standard Draft

- In the Multi-Carrier mode supported by the current 802.20 standard draft:
  - Number of Quasi-Guard subcarriers is the same as Guard subcarriers
- Multiple values of guard subcarriers are supported
  - For example, in the case of 512 FFT, the number of guard subcarriers in the PHY frame can be 32, 96, 160, …, or 416
  - MBTDD/FDD proposal was evaluated assuming 32 guard subcarriers

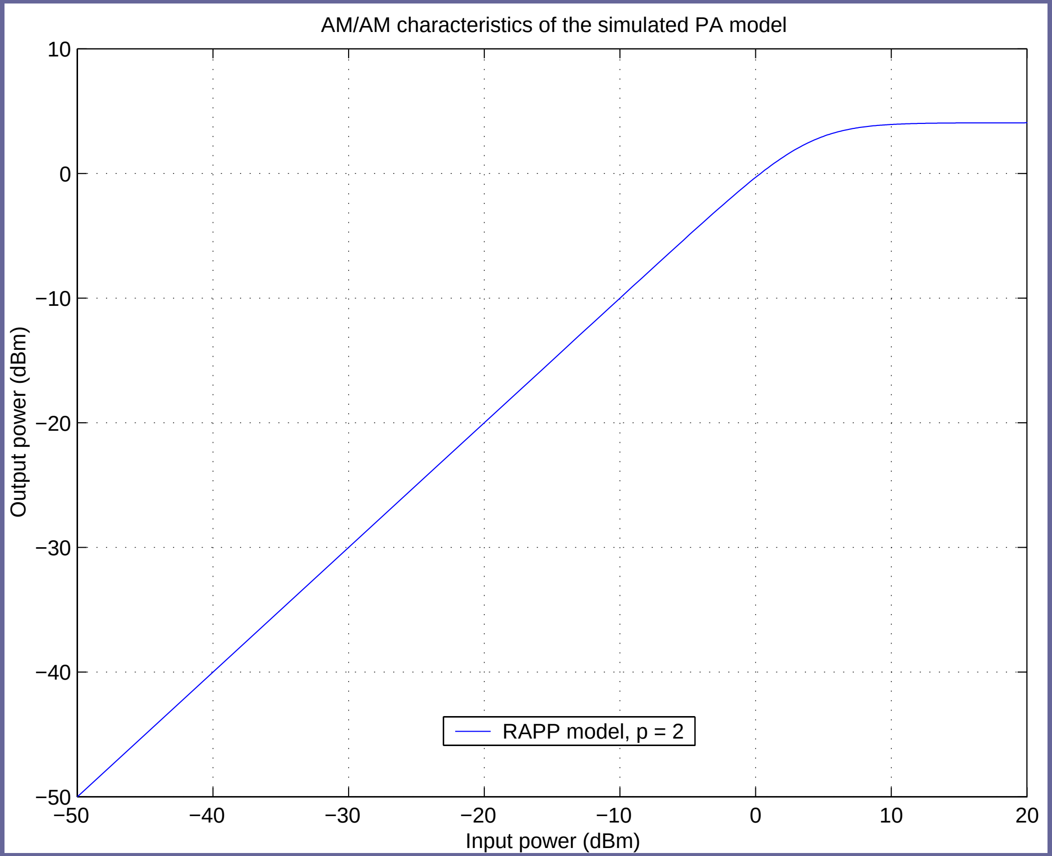
Out-of-Band Emission

- Caused by non-linearity in the transmitter
- Major, dominant source: non-linear power amplifier
- Leads to spectral re-growth of the transmit signal
- This out-of-band emission interferes with the transmission in the adjacent channel
- Adjacent channel interference can be reduced by:
  - PA backoff
  - Sufficient channel spacing or guard bands

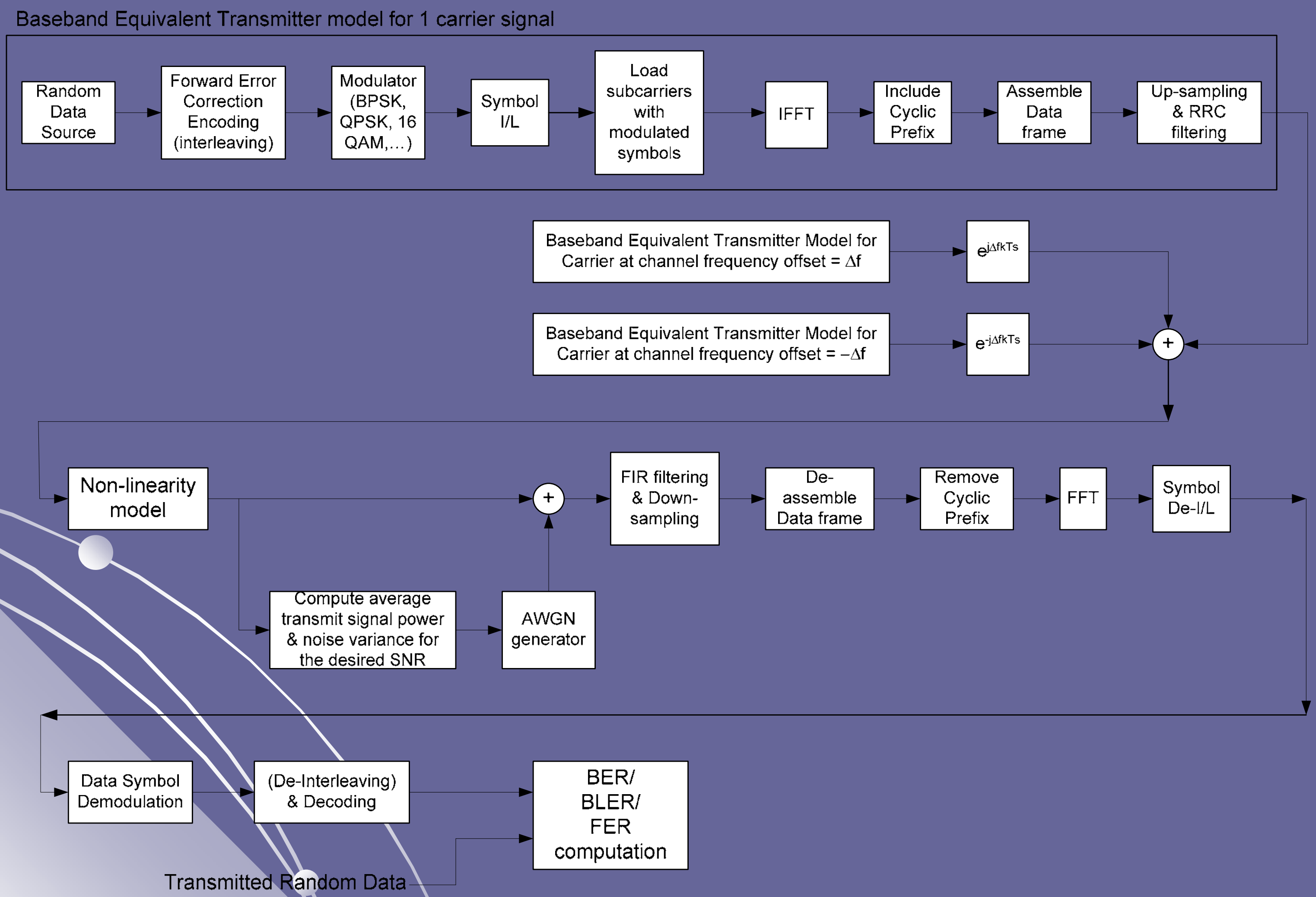
Power Amplifier Model for Simulation

- RAPP's PA model for AM/AM characteristics
- Smoothness factor, p = 2
- Output Backoff (OBO) ~ 5 dB

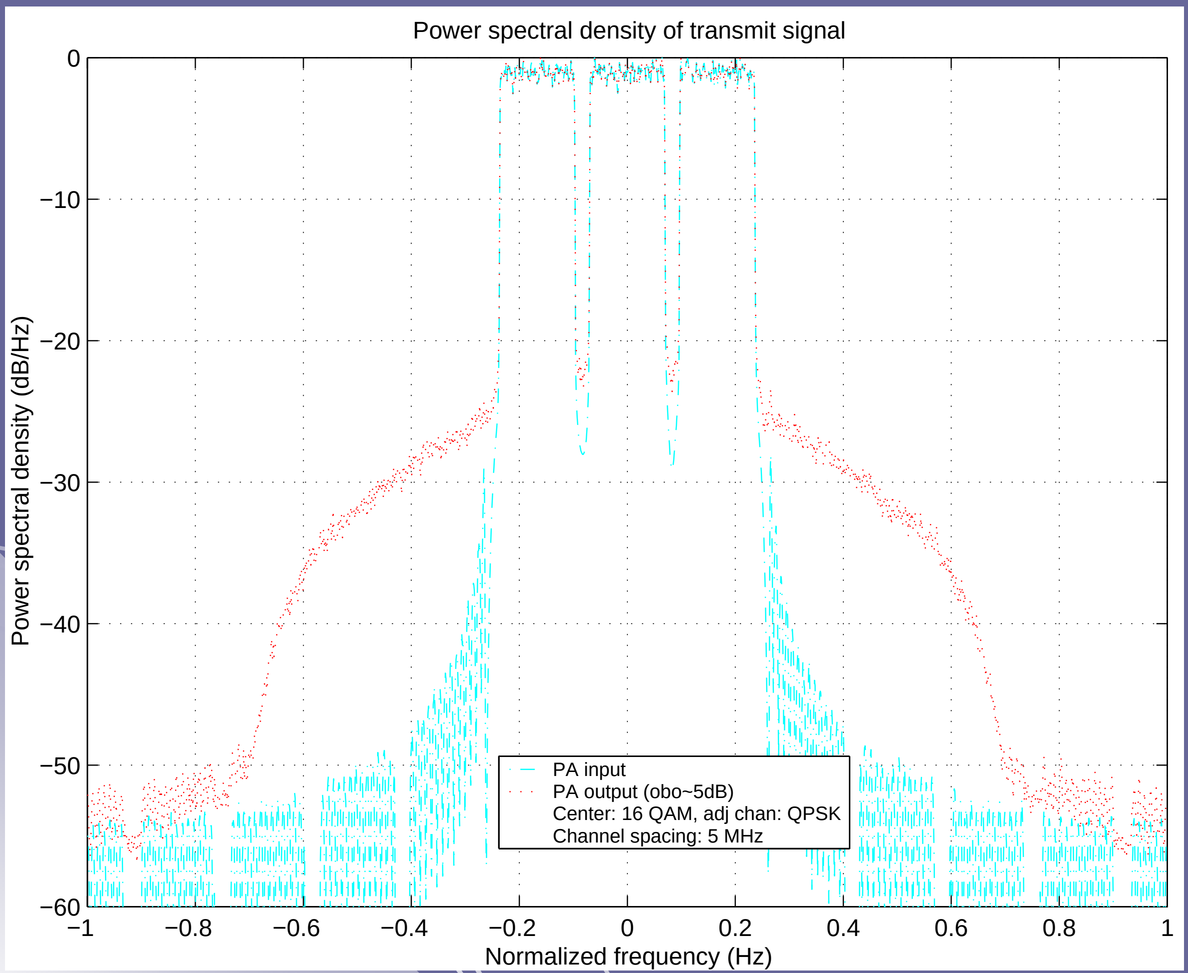
$$V_{out} = \frac{V_{in}}{\left(1 + \left(\frac{|V_{in}|}{V_{sat}}\right)^{2p}\right)^{\frac{1}{2p}}} \quad , p = 2$$



End-to-end Link Simulation Model

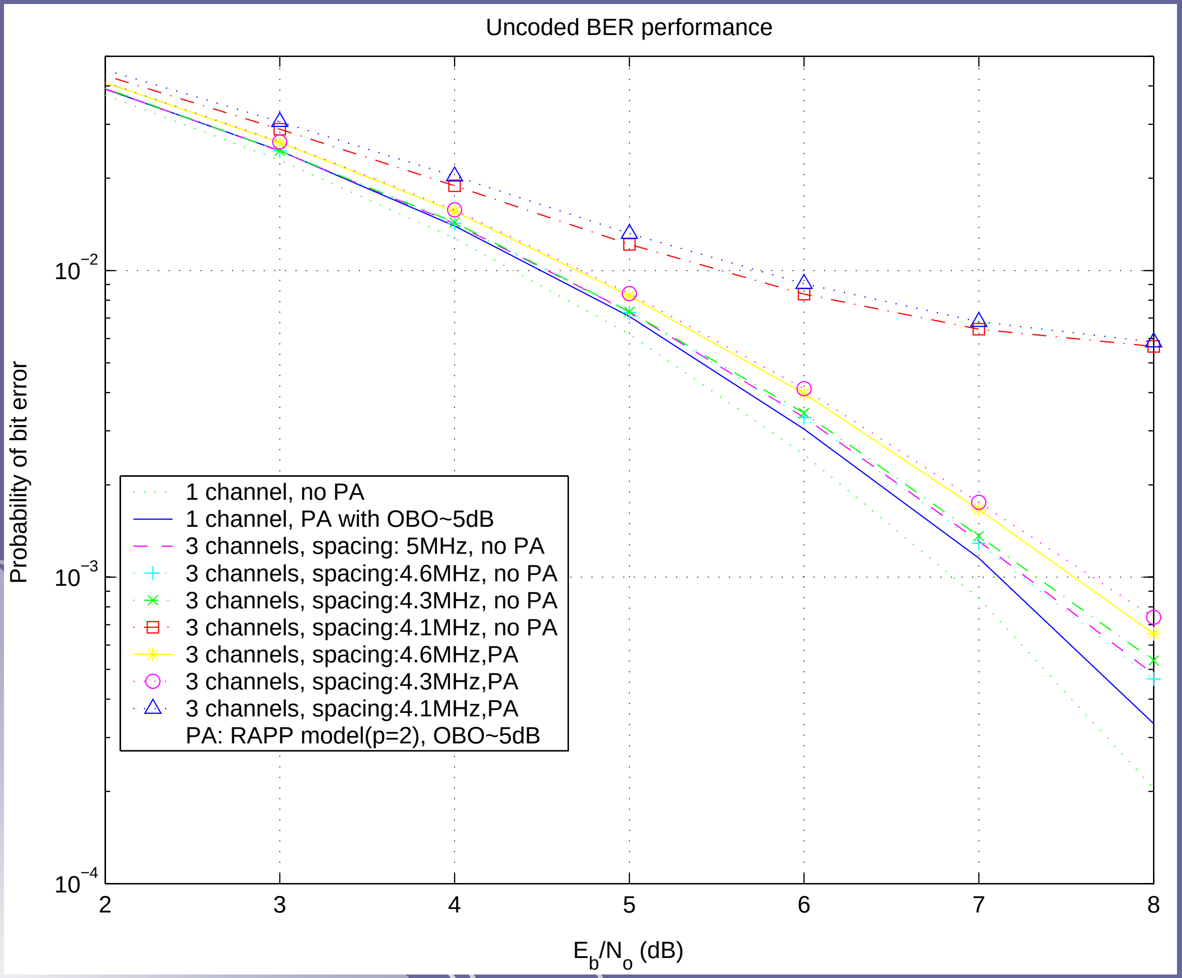


Power Spectrum of Transmit Signal



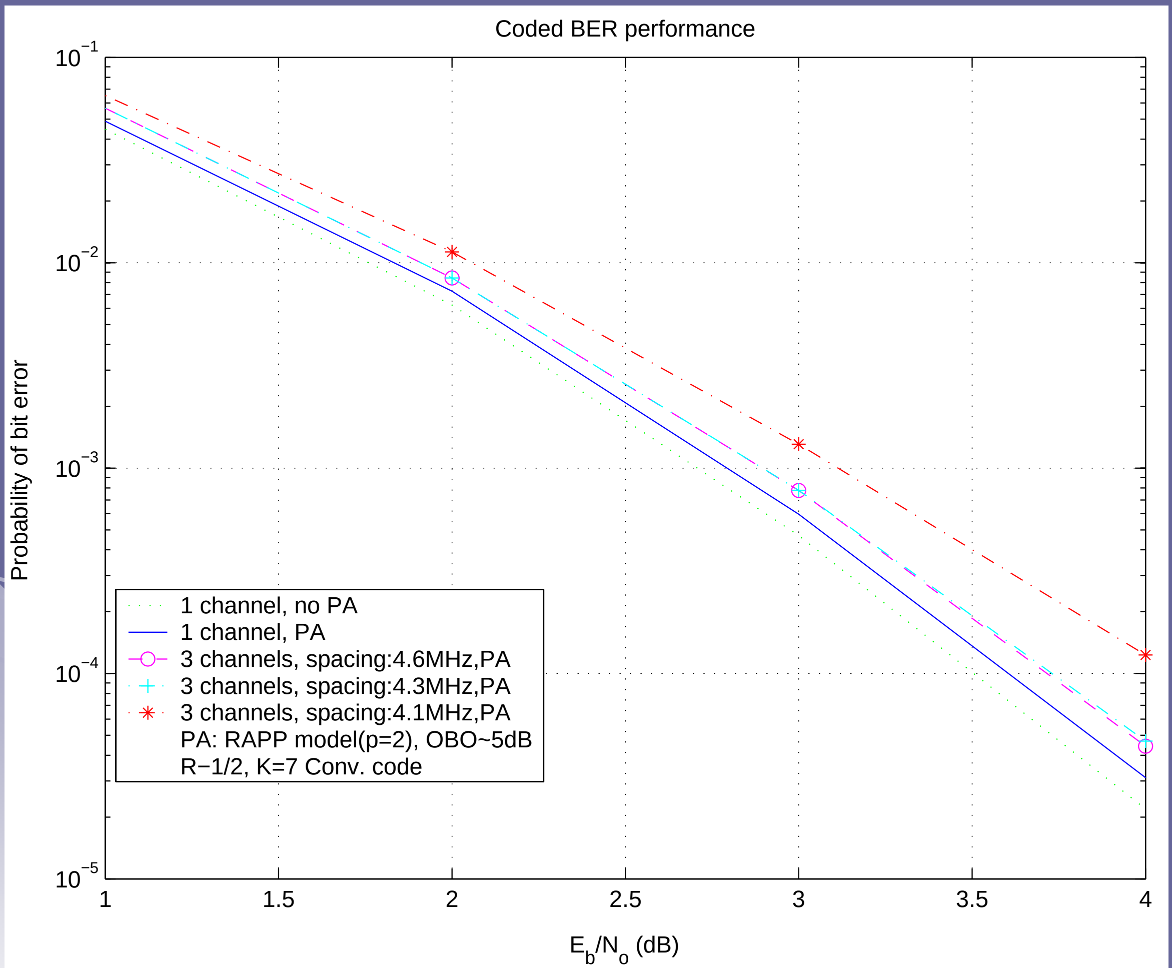
- Channel spacing:
  - 5 MHz (Δf)
- Cyan curve: Power spectral density of transmit signal at PA input
- Red curve: Transmit signal spectrum at PA output
  - Out-of-band spectral re-growth due to PA nonlinearity

Simulation Results – Uncoded QPSK



- Uncoded QPSK
- Simulated cases:
  - 1 channel
  - 3 channels with channel spacing:
    - 5, 4.6, 4.3 and 4.1MHz
- Includes effects of Power Amplifier nonlinearity
  - RAPP's model
    - p = 2
    - OBO ~ 5 dB
- Error floor for channel spacing ≤ 4.1 MHz

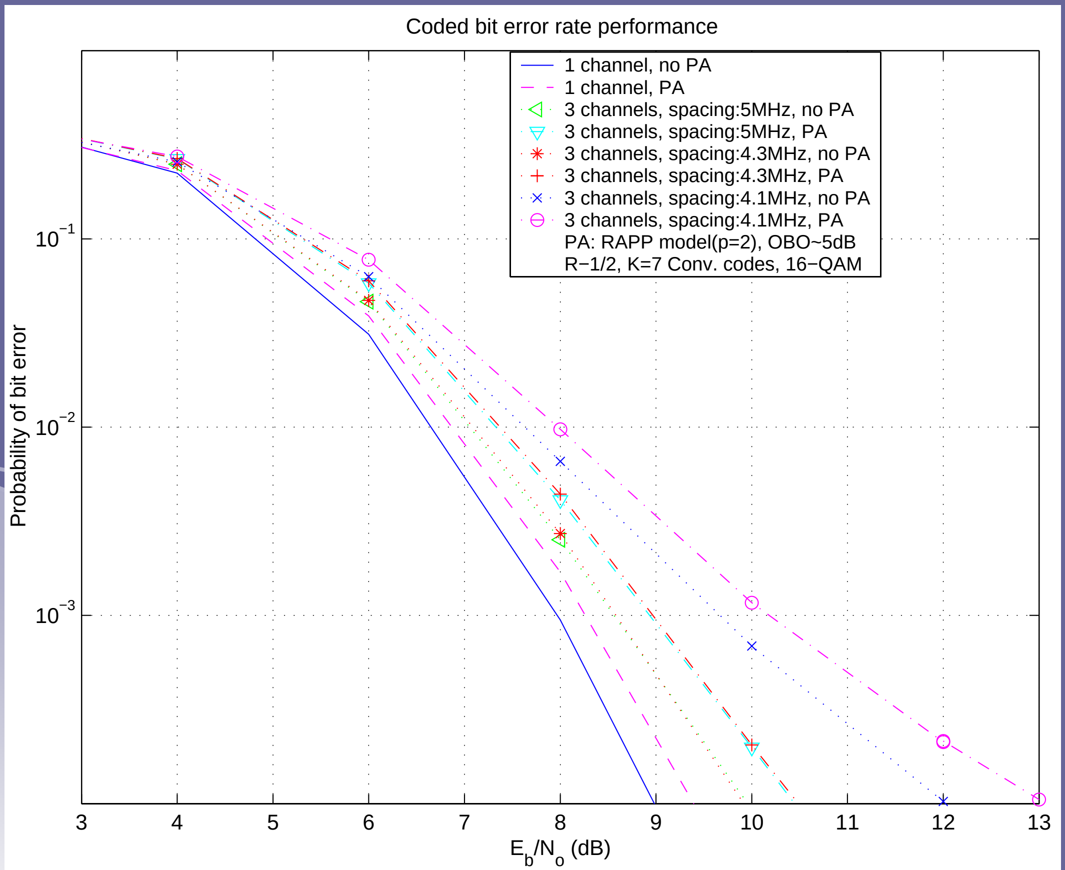
Simulation Results – Coded QPSK



- Encoded QPSK
- Simulated cases:
  - 1 channel
  - 3 channels with channel spacing:
    - 4.6, 4.3 and 4.1 MHz
- Includes effects of Power Amplifier nonlinearity
  - RAPP's model
    - p = 2
    - OBO ~ 5 dB
- Degradation ~0.6 dB at BER=10^{-4} for channel spacing at 4.1 MHz

  => Error floor significantly reduced

Simulation Results – Encoded 16-QAM



- Encoded 16-QAM
- Simulated cases:
  - 1 channel
  - 3 channels with channel spacing:
    - 5, 4.3 and 4.1 MHz
- Includes effects of Power Amplifier nonlinearity
  - RAPP's model
    - p = 2
    - OBO ~ 5 dB
- Degradation at BER=10^{-4} for channel spacing at 4.1 MHz
  - ~3.0 dB without PA nonlinearity
  - ~4.0 dB with PA nonlinearity

  => More significant degradation than QPSK

Performance degradation with respect to single channel

- Reference case: Uncoded QPSK with PA nonlinearity
- 3 channels with channel spacing:
  - ≥ 0.92, 0.86 and 0.82 Δf (Δf = 5 MHz), i.e., $\geq$ 4.6, 4.3 and 4.1 MHz
- RAPP's PA model with p = 2, OBO ~ 5 dB

BER	Channel Spacing		
	$\geq 0.92\ \Delta f$	$= 0.86\ \Delta f$	$= 0.82\ \Delta f$
10^{-2}	0.2 dB	0.23 dB	1.2 dB
10^{-3}	0.45 dB	0.55 dB	>10 dB

- Encoded QPSK
  - Convolutional code
  - Random symbol interleaving across subcarriers

BER	Channel Spacing		
	$\geq 0.92\ \Delta f$	$= 0.86\ \Delta f$	$= 0.82\ \Delta f$
10^{-3}	0.10 dB	0.10 dB	0.3 dB
10^{-4}	0.10 dB	0.12 dB	0.46 dB

Performance Degradation:16-QAM

- Encoded 16-QAM
  - Convolutional code
  - Random symbol interleaving across subcarriers
- 3 channels with channel spacing:
  - $\geq$ 0.86, 0.82 Δf (Δf = 5 MHz)
  - i.e., $\geq$ 4.3, 4.1MHz

BER	1 Channel With PA	Channel Spacing			
		$\geq 0.86\ \Delta f$		$= 0.82\ \Delta f$	
		No PA	PA	No PA	PA
10^{-3}	0.3 dB	0.6 dB	1.0 dB	1.7 dB	2.25 dB
10^{-4}	0.4 dB	0.9 dB	1.5 dB	3.0 dB	4.0 dB

Proposed Changes to the current Standard Draft

- Changes to Section 8.1.11
- To support the proposed feature, a new protocol constant can be added: NQuasiGuard,PR, for use in the MultiCarrier ON mode.
- Changes to Section 6.5.6.1
- A new field can be added to the SystemInfo block: NumQuasiGuardSubcarriers. The new field needs to be transmitted in the SystemInfo block when the number of carriers per sector is greater than one, i.e., in the MultiCarrier ON mode.
- Changes to Section 9.3.2.2.2
- "… The set of quasi-guard subcarriers in the superframe preamble shall be the subcarriers numbered Ncarrier_size*m – NQuasiGuard,PR /2 through Ncarrier_size*m + NQuasiGuard,PR /2 – 1 where m =. 1, …, Ncarriers – 1. The set of quasi-guard subcarriers in each FL shall be the subcarriers numbered Ncarrier_size*m – NQuasiGuard /2 to Ncarrier_size*m + NQuasiGuard /2 - 1 where m =. 1, …, Ncarriers – 1. The quantity NQuasiGuard is given by the NumQuasiGuardSubcarriers parameters which is part of the public data of the Overhead Messages Protocol."
- Changes to Section 9.4.1.2.2
-
- "…The set of quasi-guard subcarriers in each RL shall be the subcarriers numbered Ncarrier_size*m – NQuasiGuard /2 to Ncarrier_size*m + NQuasiGuard /2 - 1 where m =. 1, …, Ncarriers – 1. The number of quasi-guard subcarriers NQuasiGuard for the reverse link shall be the same as the number of quasi-guard subcarriers on the reverse link, as given by NumQuasiGuardSubcarriers, which is part of the public data of the Overhead Messages Protocol for any sector…."

Conclusion

- By allowing the number of quasi-guard subcarriers to be a parameter that is different from the number of guard subarriers, the standard will be more flexible in supporting various system deployment scenarios so as to achieve higher spectral efficiency in a licensed spectral block

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