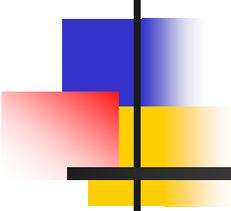




# Rate Matching Improvement Using Mixed Modulation Method

A decorative graphic consisting of a vertical black line intersecting a horizontal black line. To the left of the intersection, there are three overlapping squares: a blue one on top, a red one on the left, and a yellow one on the bottom.

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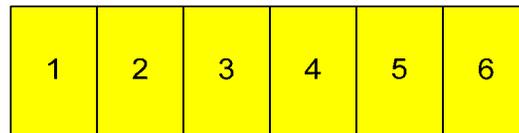
## Background

- To provide capacity achieving performance, it is desirable to have certain rate matching granularity.
- Currently rate matching is done by selecting modulation order and varying coding rate by puncturing.
- Code puncturing is necessary for various reasons, one of which is due to limited granularity of modulation schemes. However, aggressive puncturing reduces coding and diversity gain.
- Using mixed order of modulation provides an alternative way to perform rate matching, and superior performance by reducing puncturing.
- Using mixed order of modulation can also eliminate the need for additional modulation schemes such as 8PSK

## Concept of mixed modulation

- Mix more than one modulation orders within one data block.
- Desired data rate can be obtained by adjusting the ratio of different modulation orders
- Code puncturing can be eliminated or reduced
- Can replace some non-square modulation schemes such as 32 QAM or 8PSK

Symbol mapper output:  
Conventional modulation



Symbol mapper output:  
mixed modulation



8PSK



QPSK

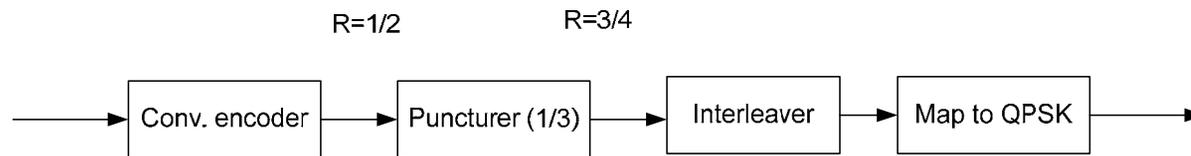


16QAM

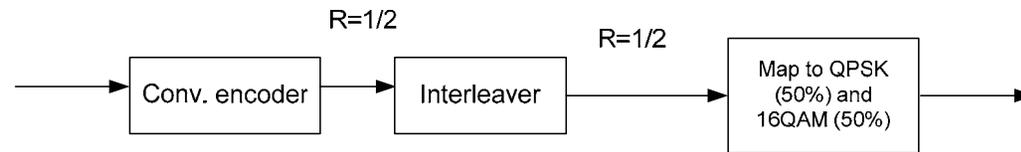
## Example of MCS schemes using mixed modulation

Data rate (bit/sec/Hz)	Existing Method		Proposed Method	
	modulation	Code rate	modulation	Code rate
0.75	BPSK	3/4	BPSK + QPSK	1/2
1.5	QPSK	3/4	QPSK + 16Q AM	1/2

# Example of using mixed modulation to eliminate puncturing

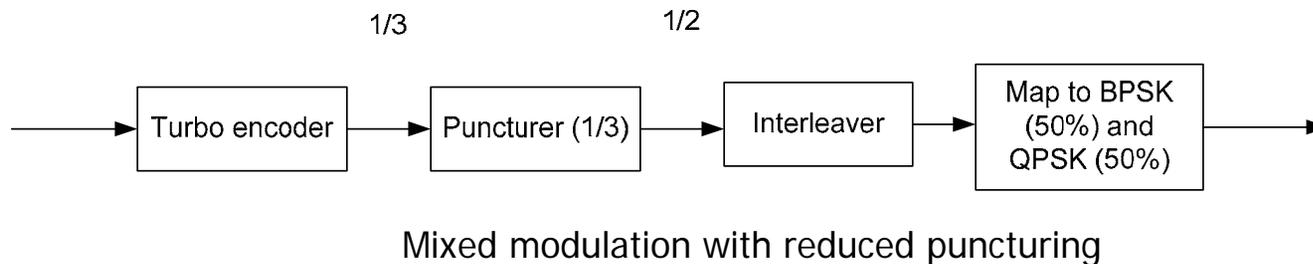
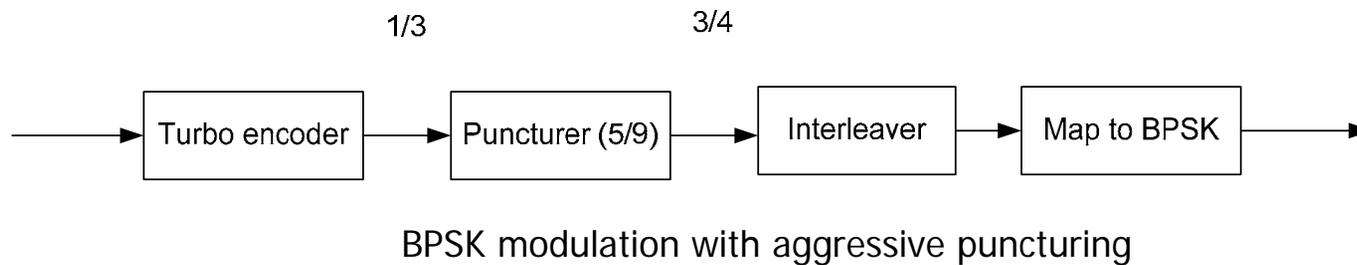


QPSK modulation with puncturing

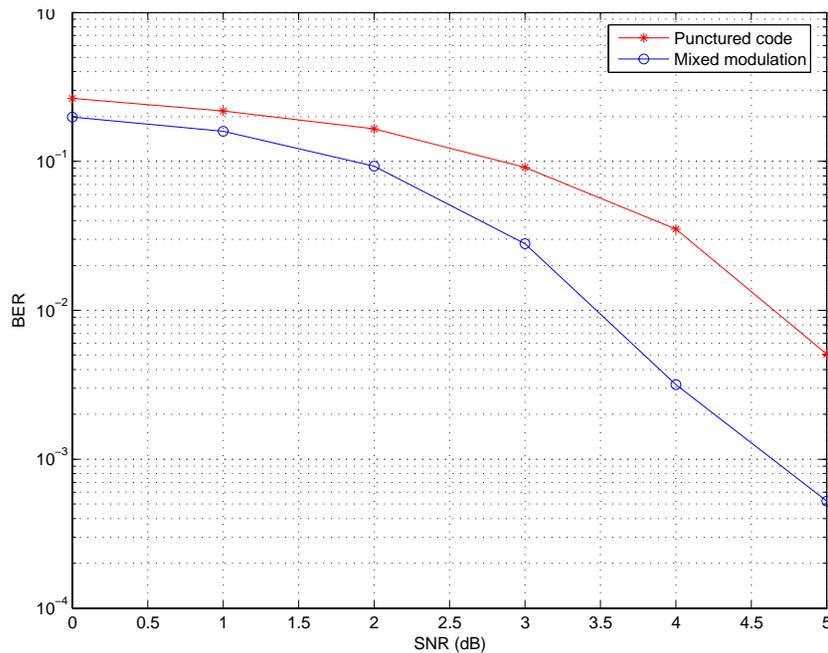


Mixed modulation without puncturing

## Example of using mixed modulation to reduce puncturing

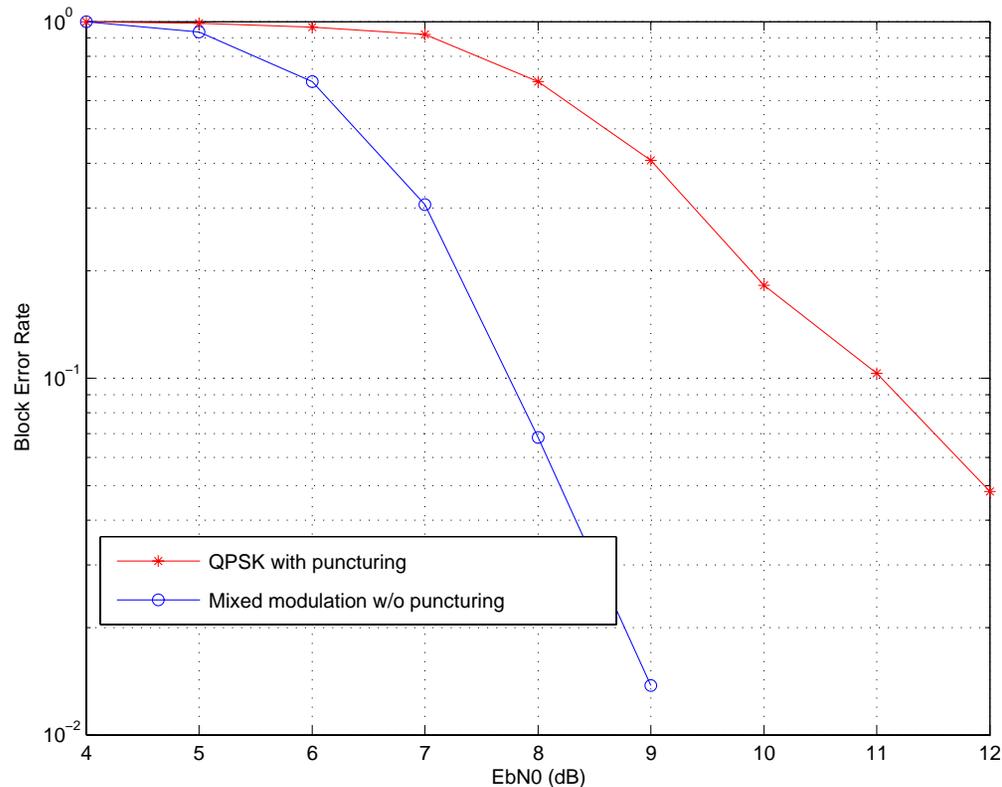


## Performance comparison in AWGN channel



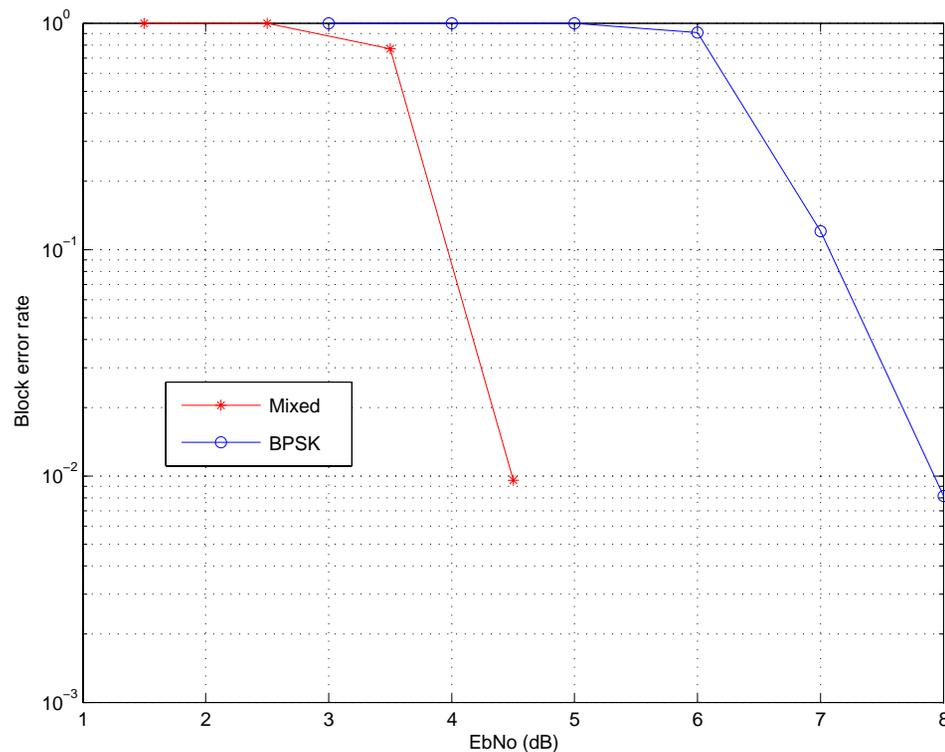
- 64 state convolutional code
- Rate  $\frac{1}{2}$  code is punctured to  $\frac{3}{4}$  for BPSK.
- Unpunctured code is mapped to mixed BPSK (50%) and QPSK (50%).
- Both achieve same data rate  $R = 0.75$  bit/sec/Hz.
- Mixed modulation has approximately 1.2 dB advantage at 1% BER

## Performance comparison in fast fading channel



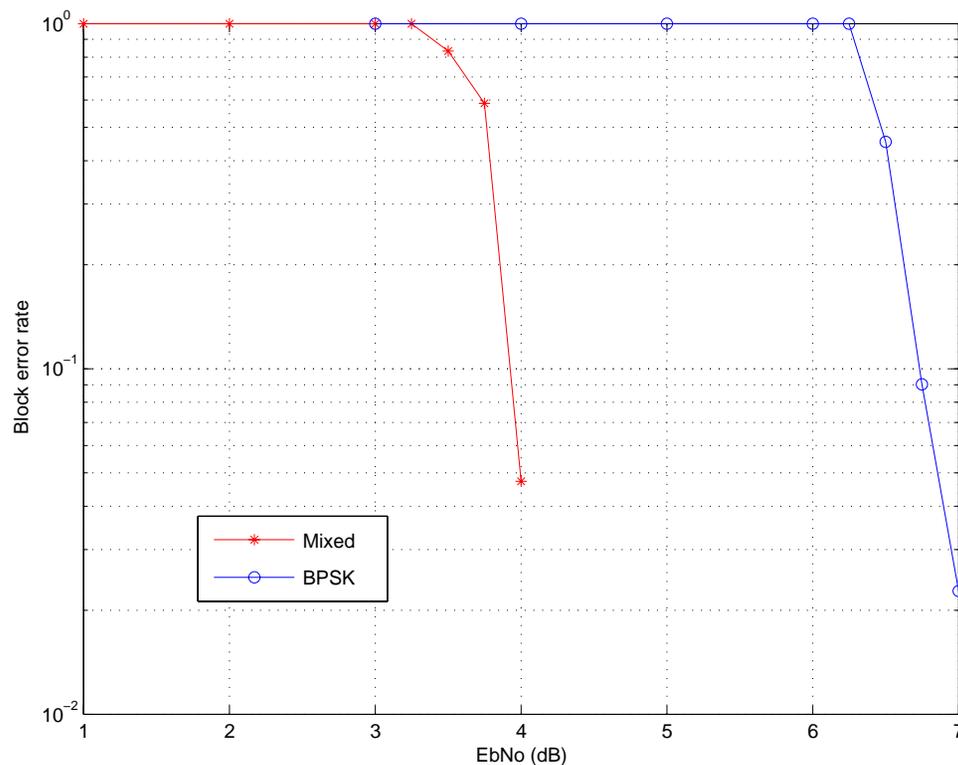
- 256 state Convolutional code
- Rate  $\frac{1}{2}$  code is punctured to  $\frac{3}{4}$  for QPSK.
- Unpunctured code is mapped to mixed QPSK (50%) and 16QAM (50%).
- Both achieve same data rate  $R = 1.5$  bit/sec/Hz.
- $\sim 3$  dB gain at 10% BLER
- Sharper slope of mixed modulation indicates higher diversity order

# Performance comparison with Turbo coding in fast Rayleigh fading



- 1/3 Turbo code punctured into  $3/4$  rate for BPSK, and  $1/2$  rate for mixed modulation (50% BPSK/ 50% QPSK).
- Both achieve same data rate  $R = 0.75$  bit/Sec/Hz
- Block size = 512 bit
- $\sim 3$  dB gain at 10% BLER

## Performance comparison with Turbo coding in fast fading channel



- 1/3 Turbo code punctured into  $\frac{3}{4}$  rate for BPSK, and  $\frac{1}{2}$  rate for mixed modulation (50% BPSK/ 50% QPSK). Both achieve same data rate  $R = 0.75$  bit/Sec/Hz.
- Block size = 2048 bit
- ~2.8 dB gain at 10% BLER

## Mixed modulation: trade modulation loss for coding gain

- Mixed modulation incurs performance loss due to use of higher order modulation scheme.
- However, the saved coded bits provide improved coding gain, which can overwhelm the modulation loss when modulation order is not greater than 16 QAM.
- More importantly, the saved bits improve diversity order in bit-interleaved systems, therefore providing superior performance in multipath fading channels.

## Summary

- We propose to use mixed modulation to perform rate matching, combined with code puncturing.
- Benefits of mixed modulation include
  - Improved coding gain, which can overcome the loss due to higher order modulation
  - Increased diversity gain in fading channels
  - Fine granularity of rate control by changing ratio of different modulation order
  - Eliminate the need for additional modulation schemes.

## Reference

- Zehavi, "8PSK trellis codes for a Rayleigh channel," IEEE Transactions on communications, Vol. 40, 1992, pp 873-884
- Caire, et.al. "Bit-interleaved coded modulation," IEEE Transactions on information theory, Vol. 44 ,1998, pp. 927-946
- Cain, et.al. "Punctured convolutional codes of rate  $(n-1)/n$  and simplified maximum likelihood decoding," IEEE Transactions on information theory, vol. 25, 1979, pp.97-100