

Turbo Space-Time Coding on Correlated Channels

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Outline

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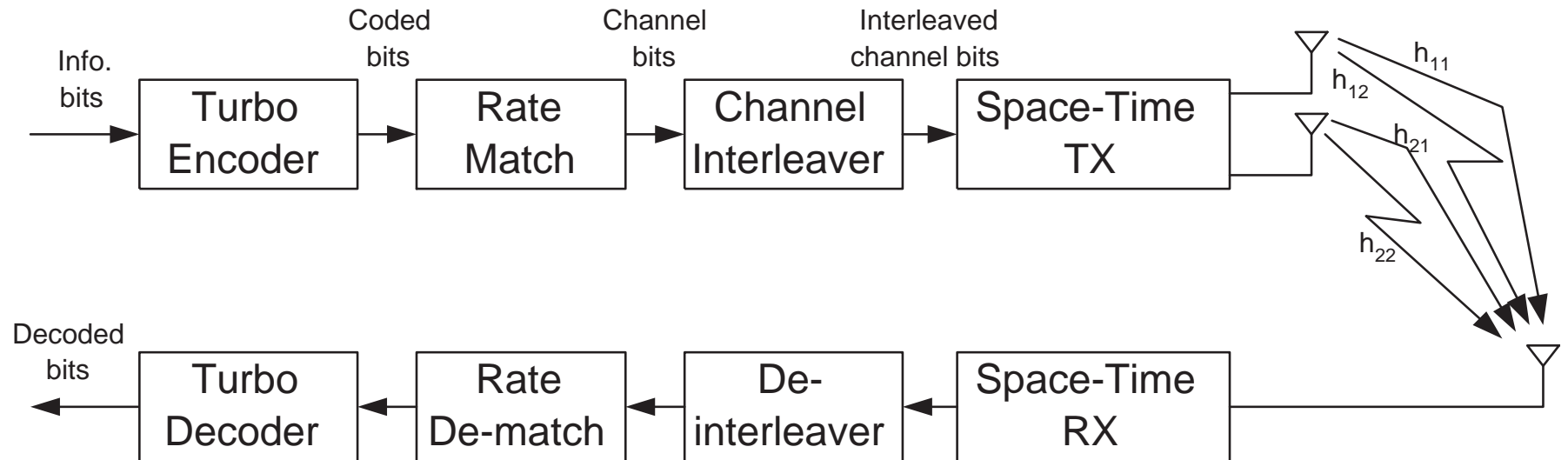
Introduction

- Turbo codes were introduced in 1993 by Berrou et al., can achieve performance close to Shannon limit.
- Adopted in W-CDMA/UMTS and CDMA2000, mainly for high data rate applications
- Space-time processing improves the performance and increases the capacity.
 - antenna diversity, rake, multiple input multiple output (MIMO)
- Turbo coded downlink diversity provides a practical and relatively low cost solution for downlink
- However, the combination of these two techniques is not well studied, especially over correlated channels.

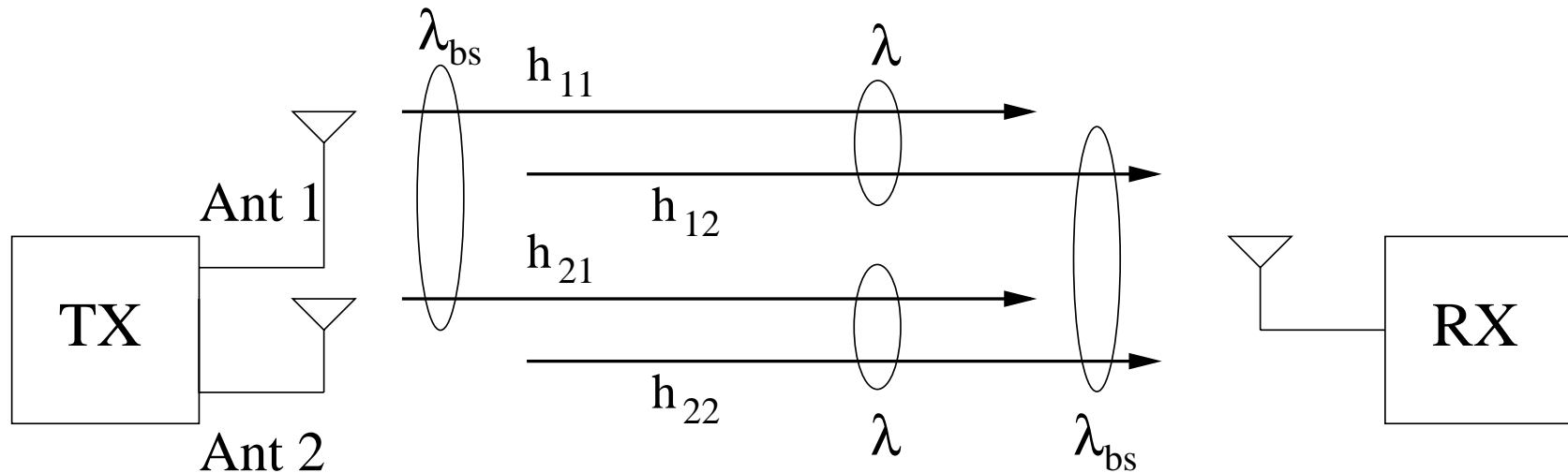
Objectives

- Evaluate a simple turbo space-time coding scheme: turbo coded W-CDMA systems with downlink space-time transmit diversity (STTD).
- Study impact of temporal and spatial correlations
 - temporal correlation: imperfect interleaving, delay constraints, buffering limitations
 - spatial correlation between multipath branches: overlapped pulse shaping filtering, correlated scattering
 - spatial correlation between antennas: limited antenna spacing, angle of arrival, angle spread
- Evaluate potential gains by using STTD in turbo coded W-CDMA systems

System Model of Turbo Coded W-CDMA Downlink

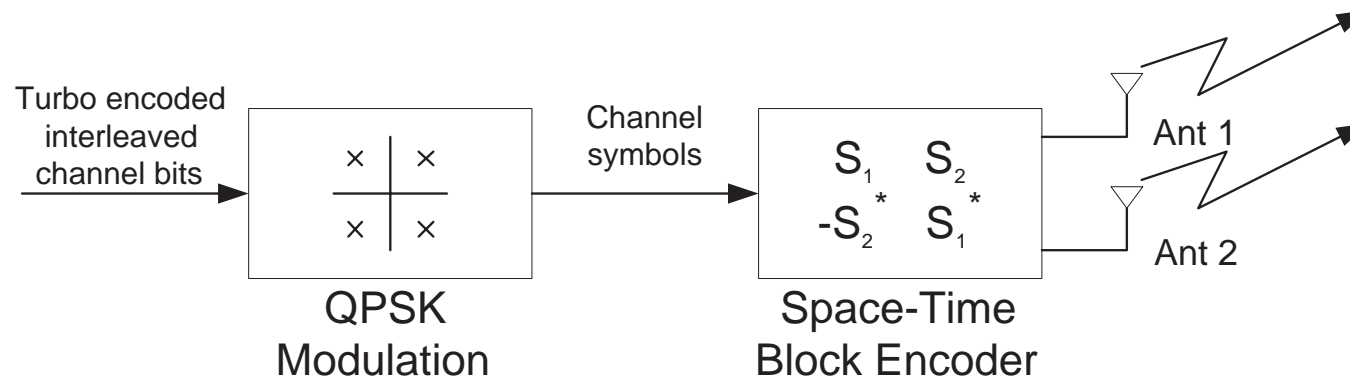


Temporal and Two Types of Spatial Correlations



- Temporal correlation over each multipath branch
- Two types of spatial correlations
 - $\lambda \equiv$ spatial correlation coefficient between multipath branches
 - $\lambda_{bs} \equiv$ spatial correlation coefficient between transmit antennas

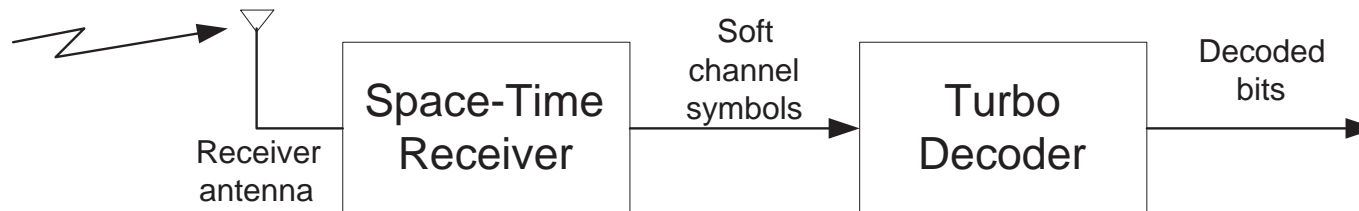
Space-Time Transmit Diversity (STTD) Transmitter



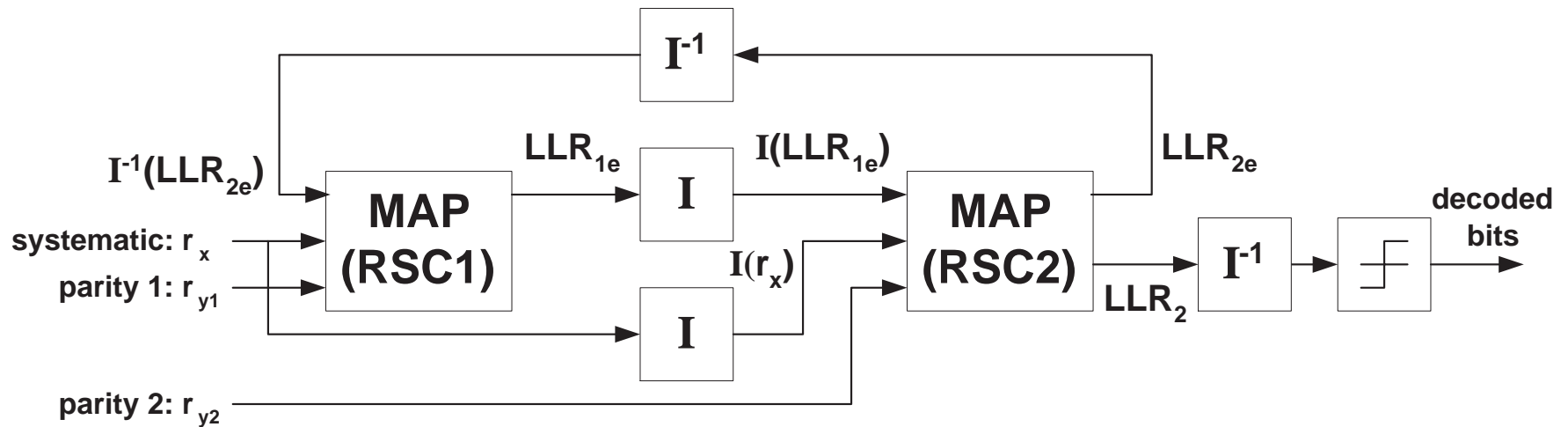
- Space-Time Block Code
 - Antenna 1 transmits symbols S_1 and S_2
 - Antenna 2 transmits symbols $-S_2^*$ and S_1^*
 - Space-time transmitter involves no bandwidth expansion

Space-Time Transmit Diversity (STTD) Receiver

- Achieves the same diversity order as maximal-ratio combining (MRC) with 1TX/2RX
- Open loop: no feedback needed



Turbo Decoding: Iterative MAP Decoding



MAP = Maximum A Posterior probability

RSC = Recursive Systematic Convolutional code

I = Interleaver

I^{-1} = Deinterleaver

LLR = Log-Likelihood Ratio

Simulation Parameters

Multipath Channel Model	2-path equal power
Correlation between 2 paths (λ)	0, 0.7, 0.9
Rayleigh Fading Model	Jakes model
Channel Estimation	ideal
Turbo Decoding Algorithm	Max-Log-MAP
Maximum Iteration Number	8
Code Rate	1/3
Frame Length	3856 (info. bits)
Rate Match	1/6 puncture
STTD	on/off
Correlation between 2 antennas (λ_{bs})	0, 0.7, 0.8
Data Rate	384kbps
Modulation	QPSK
Frame Duration	10ms

Table 1: Simulation parameters for turbo coded W-CDMA system.

STTD vs 1 Antenna: Temporal Correlation

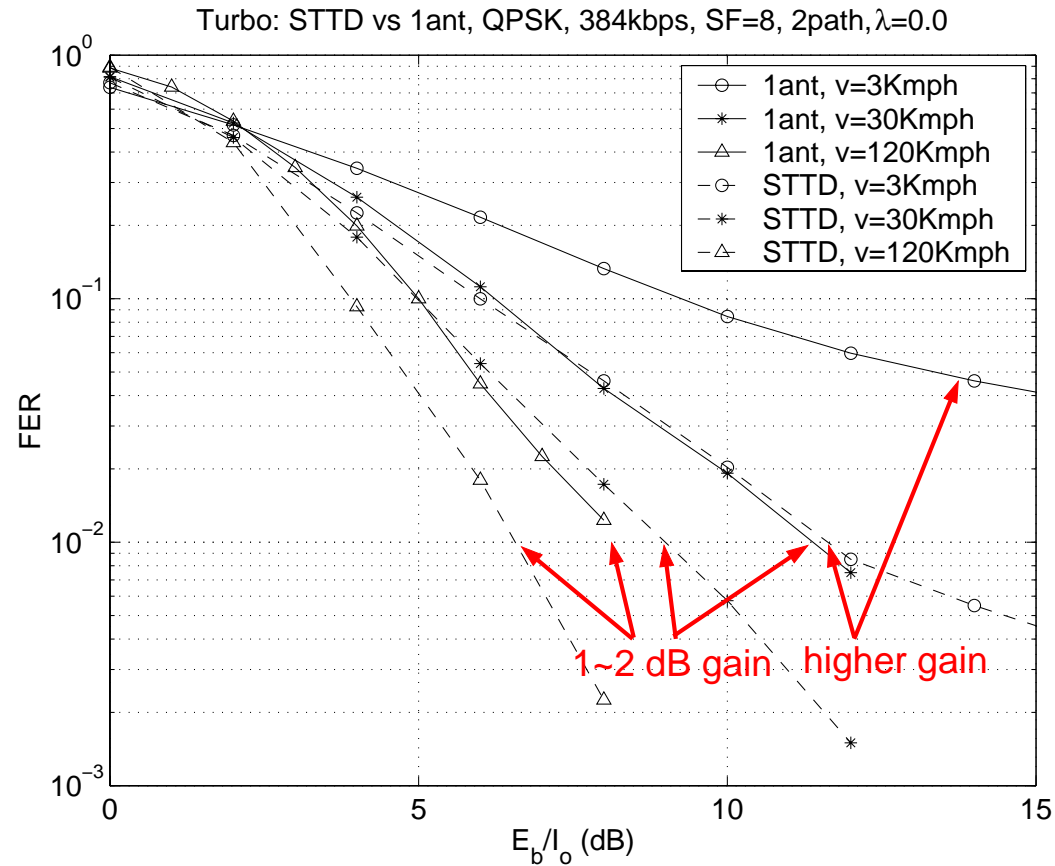


Figure 1: Turbo Coded STTD vs Turbo Coded Single Antenna: QPSK, 2-path equal power, SF=8, speed=3, 30, 120 Kmph, spatial correlation $\lambda = 0.0$.

STTD vs 1 Antenna: Multipath Spatial Correlation

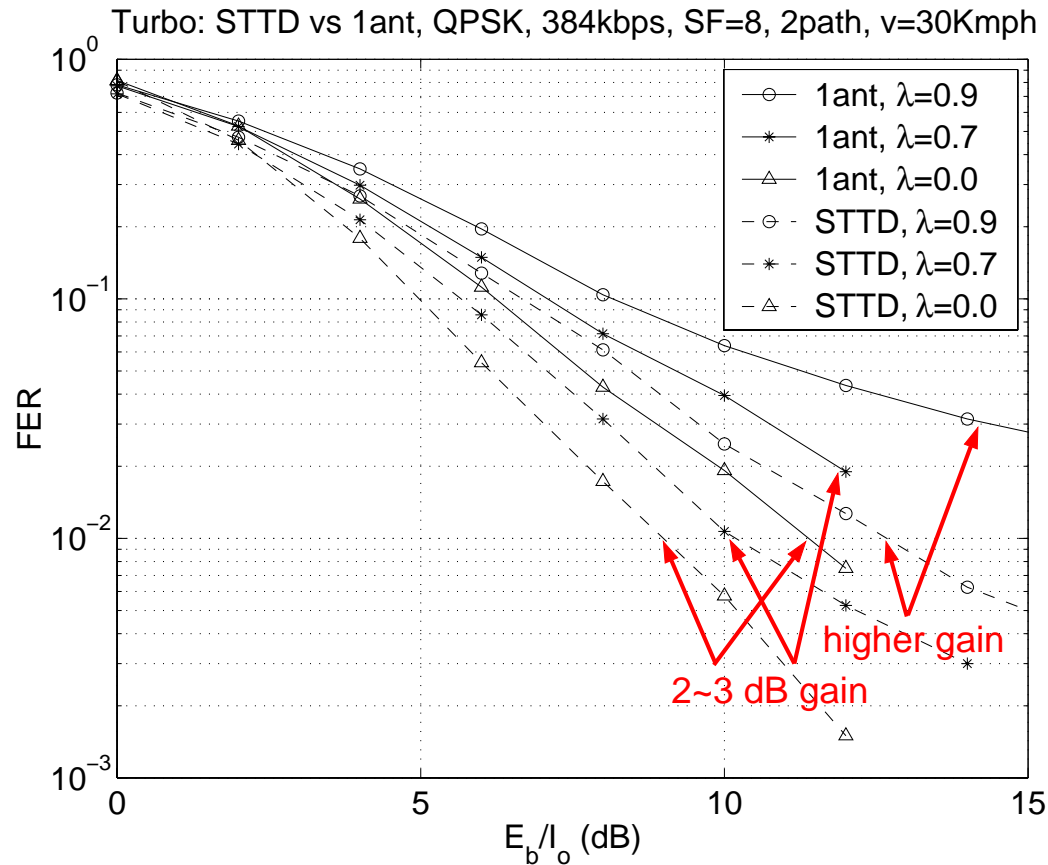


Figure 2: Turbo Coded STTD vs Turbo Coded Single Antenna: QPSK, 2-path equal power, SF=8, speed=30 Km/h, spatial correlation between multipath branches $\lambda = 0.0, 0.7, 0.9$.

STTD: Impact of TX Antenna Spatial Correlation ($\lambda_{bs} = 0.7$)

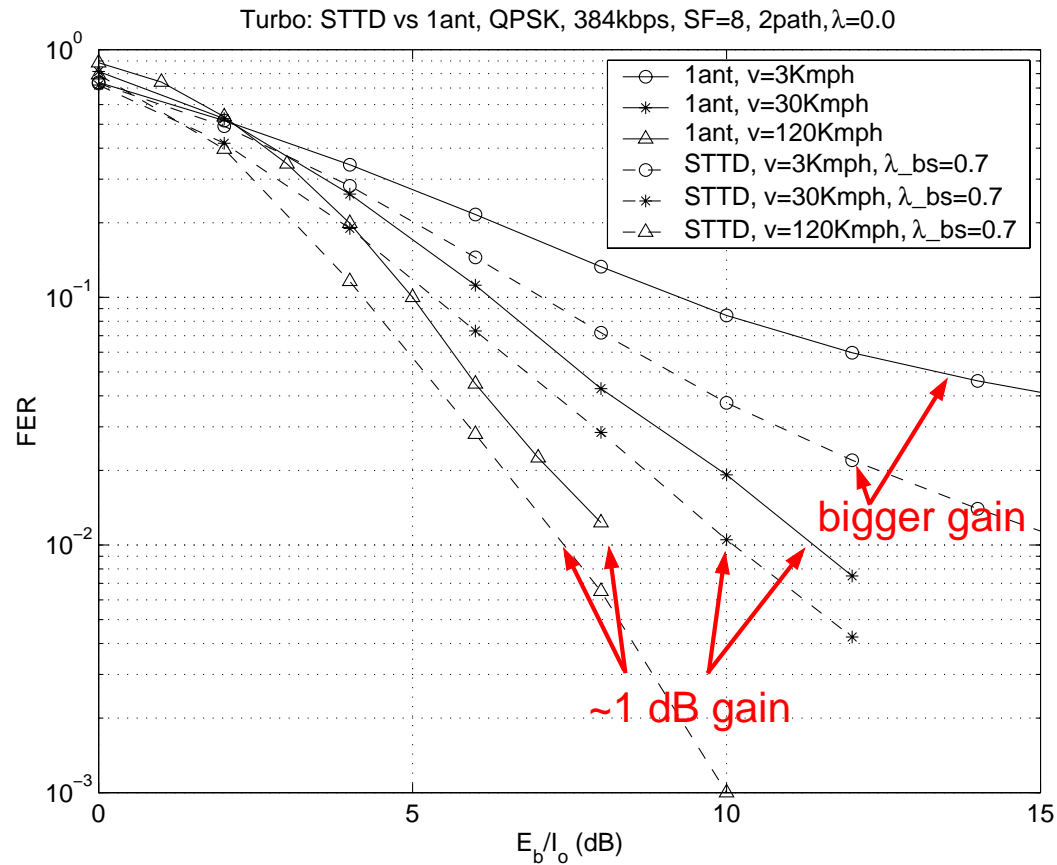


Figure 3: Turbo Coded STTD vs Turbo Coded Single Antenna: QPSK, 2-path equal power, SF=8, speed=3, 30, 120 Kmph, spatial correlation between multipath branches $\lambda = 0.0$, spatial correlation between transmit antennas $\lambda_{bs} = 0.7$.

STTD: Impact of TX Antenna Spatial Correlation ($\lambda_{bs} = 0.8$)

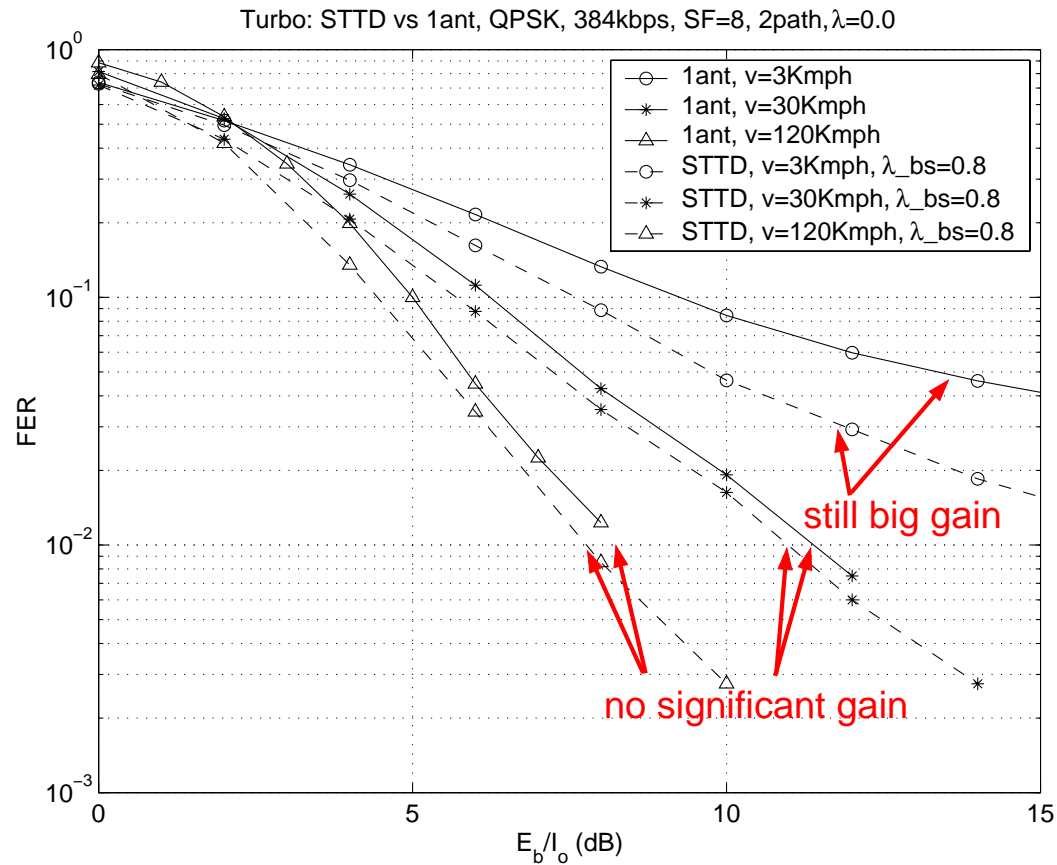


Figure 4: Turbo Coded STTD vs Turbo Coded Single Antenna: QPSK, 2-path equal power, SF=8, speed=3, 30, 120 Kmph, spatial correlation between multipath branches $\lambda = 0.0$, spatial correlation between transmit antennas $\lambda_{bs} = 0.8$.

STTD: With Two Types of Spatial Correlations

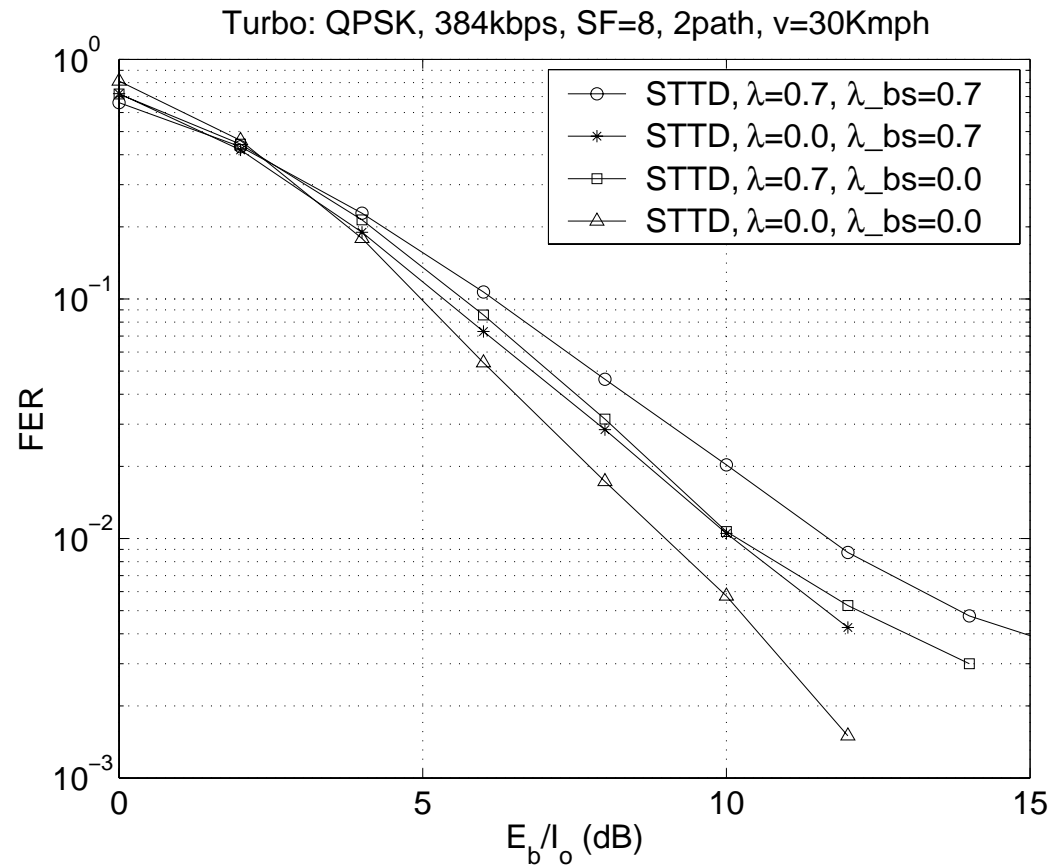


Figure 5: Turbo Coded STTD vs Turbo Coded Single Antenna: QPSK, 2-path equal power, SF=8, speed=30 Km/h. With spatial correlations between multipath branches and between transmit antennas.

Impact of Two Types of Spatial Correlations

- Spatial correlations between multipath branches and between antennas have similar effects.
- However, implementation issues are different
 - multipath diversity
 - * need rake fingers to capture, minimal cost
 - * combining signals when possible even with high correlation
 - antenna diversity
 - * the implementation cost is high
 - * balance the cost and potential gain
 - * minimize the correlation as much as possible

Summary

- Evaluated the performance of turbo coded W-CDMA systems with downlink space-time transmit diversity (STTD)
- Quantified the tolerable correlation between transmit antennas in turbo-coded W-CDMA systems with STTD, $\lambda_{bs} = 0.7$ for medium to high vehicle speeds and $\lambda_{bs} \geq 0.8$ for low vehicle speeds.
- Observed that the performance gain using turbo coded STTD is higher for higher temporal correlation (slow fading channels).