IEEE 802.16.3 Turbo Product Code
Performance Under Multipath Channels

IEEE 802.16 Presentation Submission Template (Rev. 8.21)

Document Number:

IEEE 802.16.3p-01/67

Date Submitted:

11 May, 2001

Source:

Sean Sonander	Voice:	+44(0)2380763710
Neil McSparron		
Advanced Hardware Architectures	Fax:	+44(0)2380763714
2365 NE Hopkins Court		
Pullman WA	E-mail:	sean@aha.com

Venue:

Session #13 in Orlando of the IEEE 802.16 TG3 Working Group

Base Document:

None

Purpose:

The purpose of this presentation is to provide the TG3 working group with information regarding the system CODEC

TG3 and Turbo Product Codes

Sean Sonander, Neil McSparron

Garik Markarian, Dave Williams

Allen Risley

Advanced Hardware Architectures

Turbo Product Codes

- TPCs are readily integrated into multicarrier and single carrier frameworks
- TPCs Provide high performance combined with high spectral efficiency
- TPCs have been selected in TG1
- Off the shelf chips and cores available
- TPC technology is consistent with both SS and BS target costs

Cont…

Turbo Product Codes (cont)

- The code proposed have been selected by both SC and MC ad-hoc groups for TG3
- Based on recent voting, TPCs have been selected for inclusion in TG4
- Provide outstanding performance
- Offer high flexibility

TPC – 2D Encoding Operation

- Choose coding parameters n,k
- Choose component codes, x and y
- Choose Code Parameters (n,k)
- Choose Component Codes (n_x,k_x)…
- Shorten Component Codes by ‘s’ as required

$$\boldsymbol{(n,k) = (n_x\text{-}s_x,k_x\text{-}s_x)\times(n_y\text{-}s_y,k_y\text{-}s_y)\ldots}$$

Note on Component Codes

- Component Codes based on extended Hamming Codes (Hamming Code+1 bit parity)

Extended Hamming Code	Hamming Code	Gen Poly
(8,4)	(7,4)	$x^3 + x + 1$
(16,11)	(15,11)	$x^4 + x + 1$
(32,26)	(31,26)	$x^5 + x^2 + 1$
(64,57)	(63,57)	$x^6 + x + 1$
(128,120)	(127,120)	$x^7 + x^3 + 1$
(256,247)	(255,247)	$x^8 + x + 1$

2D TPC Coding Example

- TPC Code Required: **(2304,1681)**
- Choose Component Codes (use $\sqrt{n}$)
- Extended Hamming Code **(64,57)**
- Shorten Code by 16, to make **(48,41)** code

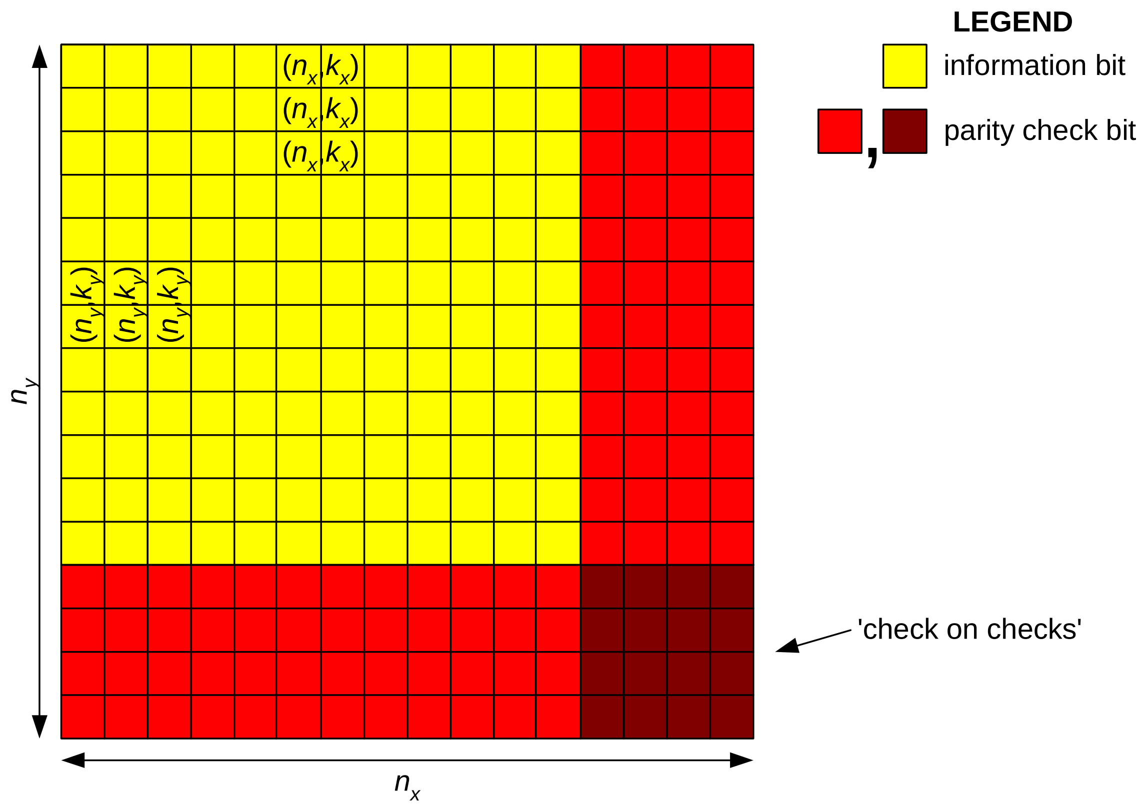
- **(48,41)** x **(48,41)** = **(2304,1681)**

2D Visualization

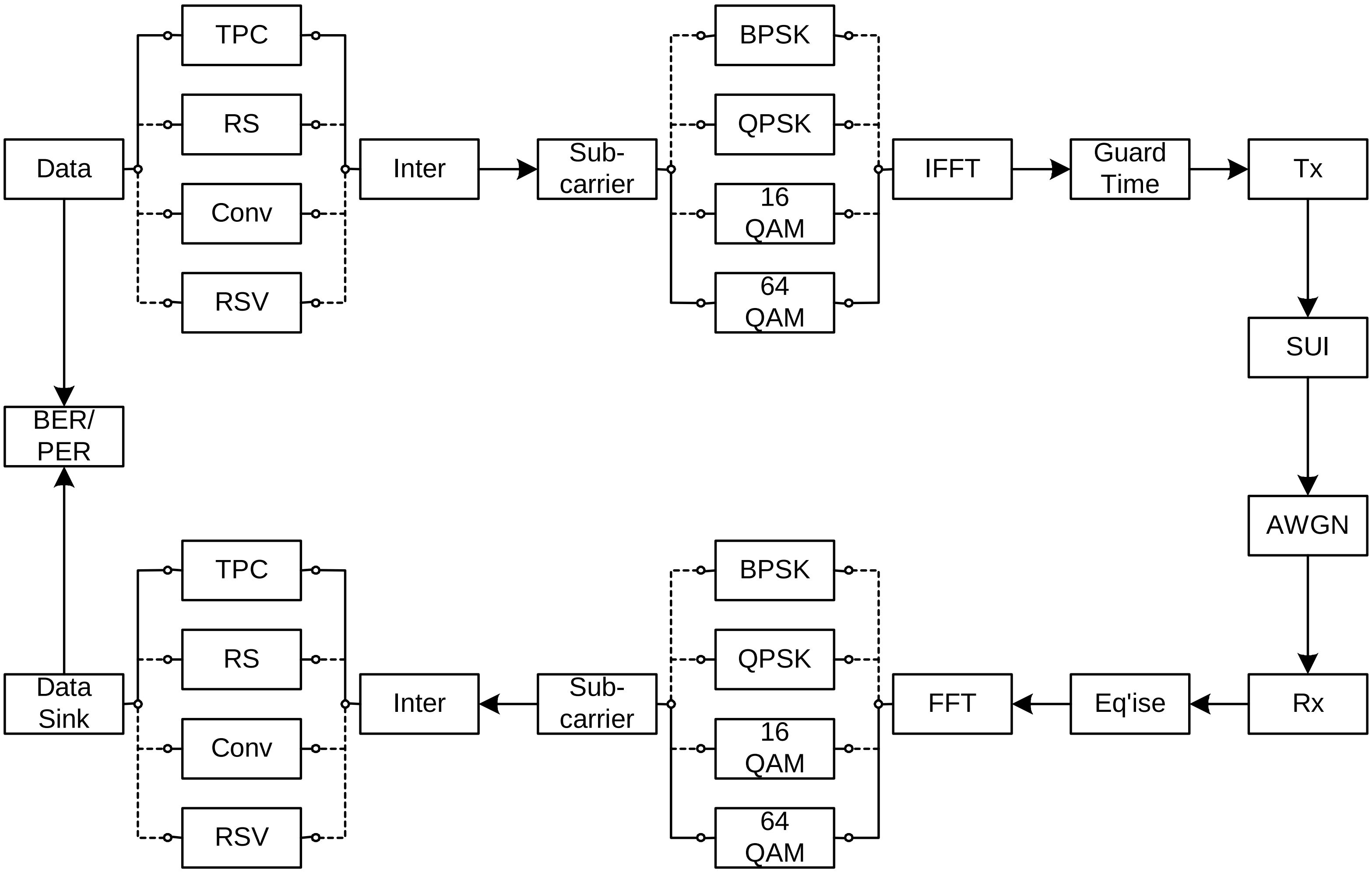
Resultant code is:

- $(n_x, k_y)\times(n_y, k_y)=(n, k)$

$$rate = \frac{k_x \times k_y}{n_x \times n_y} = \frac{k}{n}$$



Signal Path



Data
TPC
RS
Conv
RSV
Inter
Sub-carrier
BPSK
QPSK
16 QAM
64 QAM
IFFT
Guard Time
Tx
SUI
AWGN
Rx
Eq'ise
FFT
Sub-carrier
BPSK
QPSK
16 QAM
64 QAM
Inter
TPC
RS
Conv
RSV
Data Sink
BER/ PER

Channel Model

SUI 1			
Delay/s	0	4.00E-07	8.00E-07
K Direct	16	0	0
K Omni	4	0	0
Power (dB) Direct	0	-21	-32
Power (dB) Omni	0	-15	-20
Doppler (Hz)	0.4	0.4	0.4

SUI 4			
Delay/s	0	2.00E-06	4.00E-06
K Direct	0	0	0
K Omni	0	0	0
Power (dB) Direct	0	-10	-20
Power (dB) Omni	0	-4	-8
Doppler (Hz)	0.2	0.2	0.2

SUI 2			
Delay/s	0	5.00E-07	1.00E-06
K Direct	8	0	0
K Omni	2	0	0
Power (dB) Direct	0	-18	-27
Power (dB) Omni	0	-12	-15
Doppler (Hz)	0.2	0.2	0.2

SUI 5			
Delay/s	0	5.00E-06	1.00E-05
K Direct	0	0	0
K Omni	0	0	0
Power (dB) Direct	0	-11	-22
Power (dB) Omni	0	-5	-10
Doppler (Hz)	2	2	2

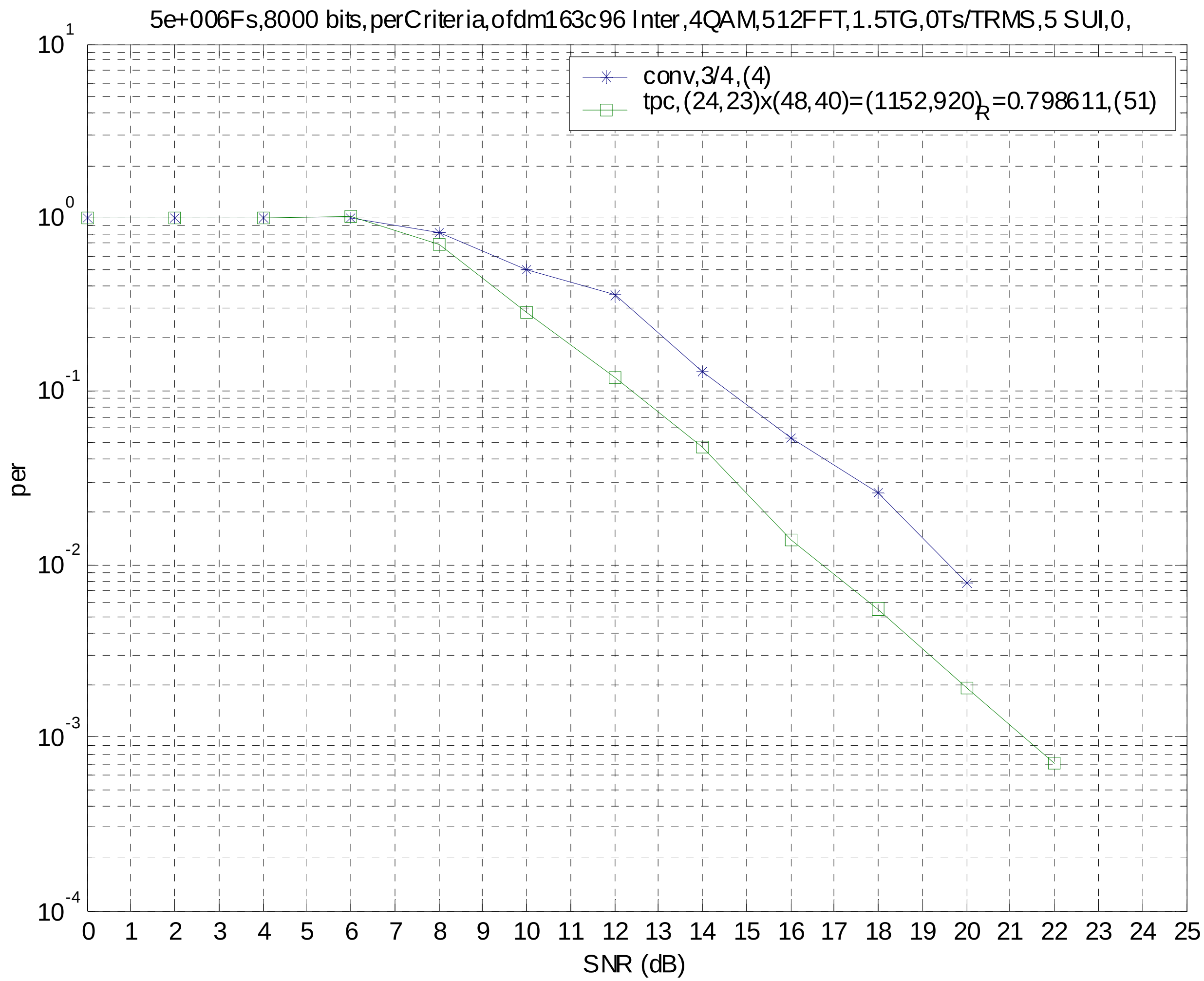
SUI 3			
Delay/s	0	5.00E-07	1.00E-06
K Direct	3	0	0
K Omni	1	0	0
Power (dB) Direct	0	-11	-22
Power (dB) Omni	0	-5	-10
Doppler (Hz)	0.4	0.4	0.4

SUI 6			
Delay/s	0	1.40E-05	2.00E-05
K Direct	0	0	0
K Omni	0	0	0
Power (dB) Direct	0	-16	-26
Power (dB) Omni	0	-10	-14
Doppler (Hz)	0.4	0.4	0.4

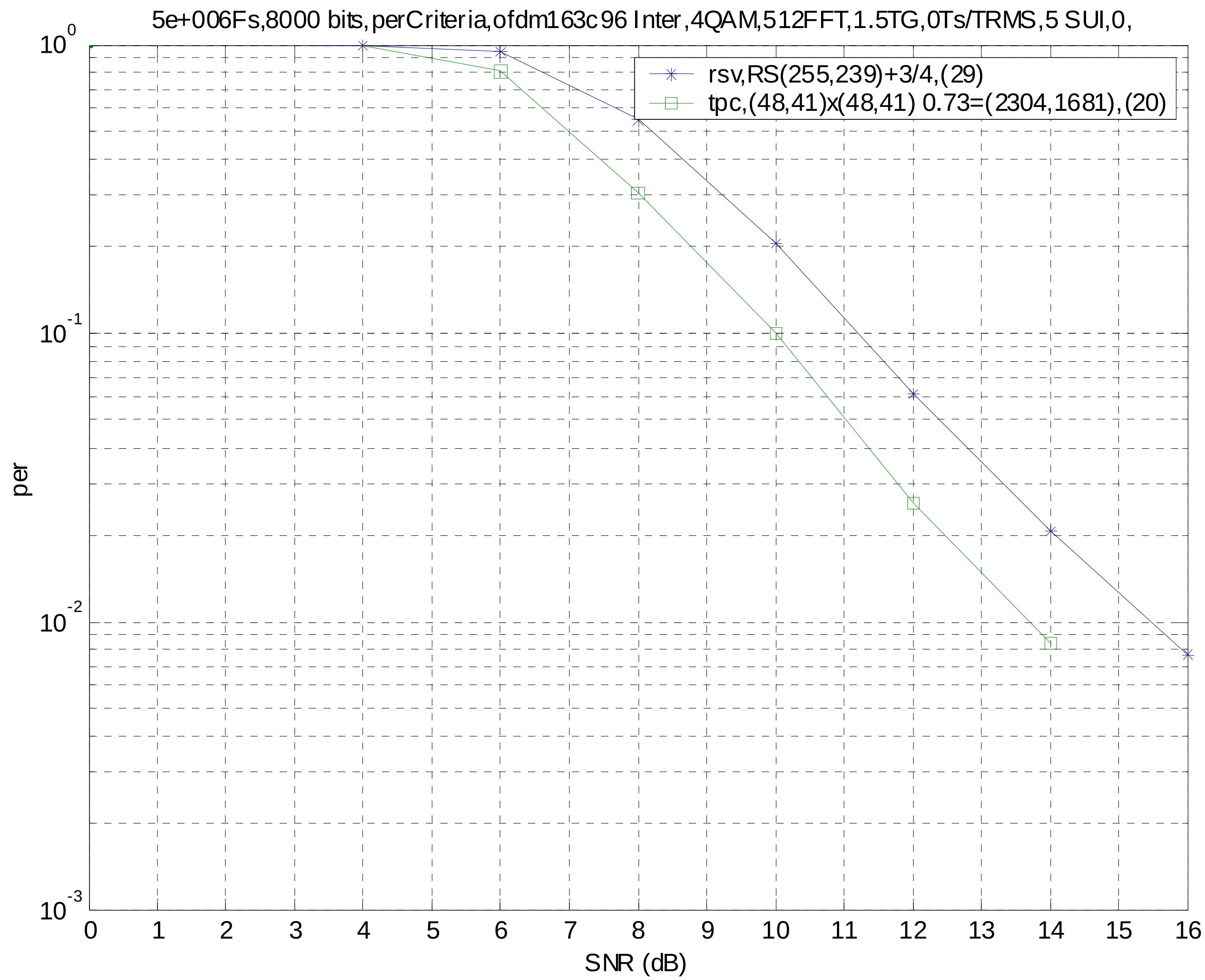
Simulation Assumptions

- Monte-Carlo Simulation, based on min errors
- Modulation QPSK, 16 QAM, 64 QAM with Gray code mapping
- Channel Model SUI 5
- 64, 512, 1024, 2048 point FFT
- Zero power penalty due to pilot/overhead transmission
- Coding: Turbo Product Coding, RSV
- Optimally weighted LLR soft metric derivation for TPC/Viterbi Decoder
- All Simulation employ channel interleaving as per proposed OFDM 16.3 method
- 1 Packet contains 8000 information bits

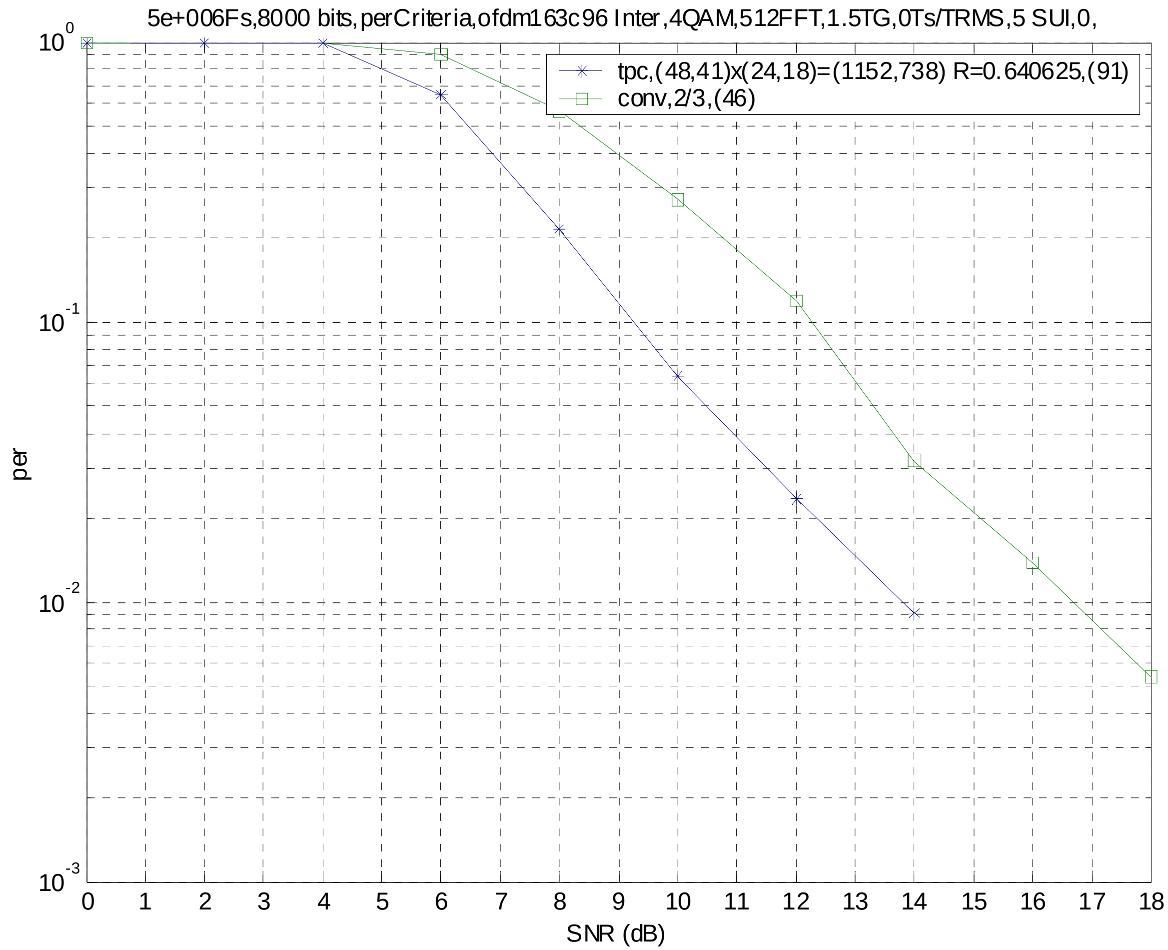
OFDM Results



OFDM Results



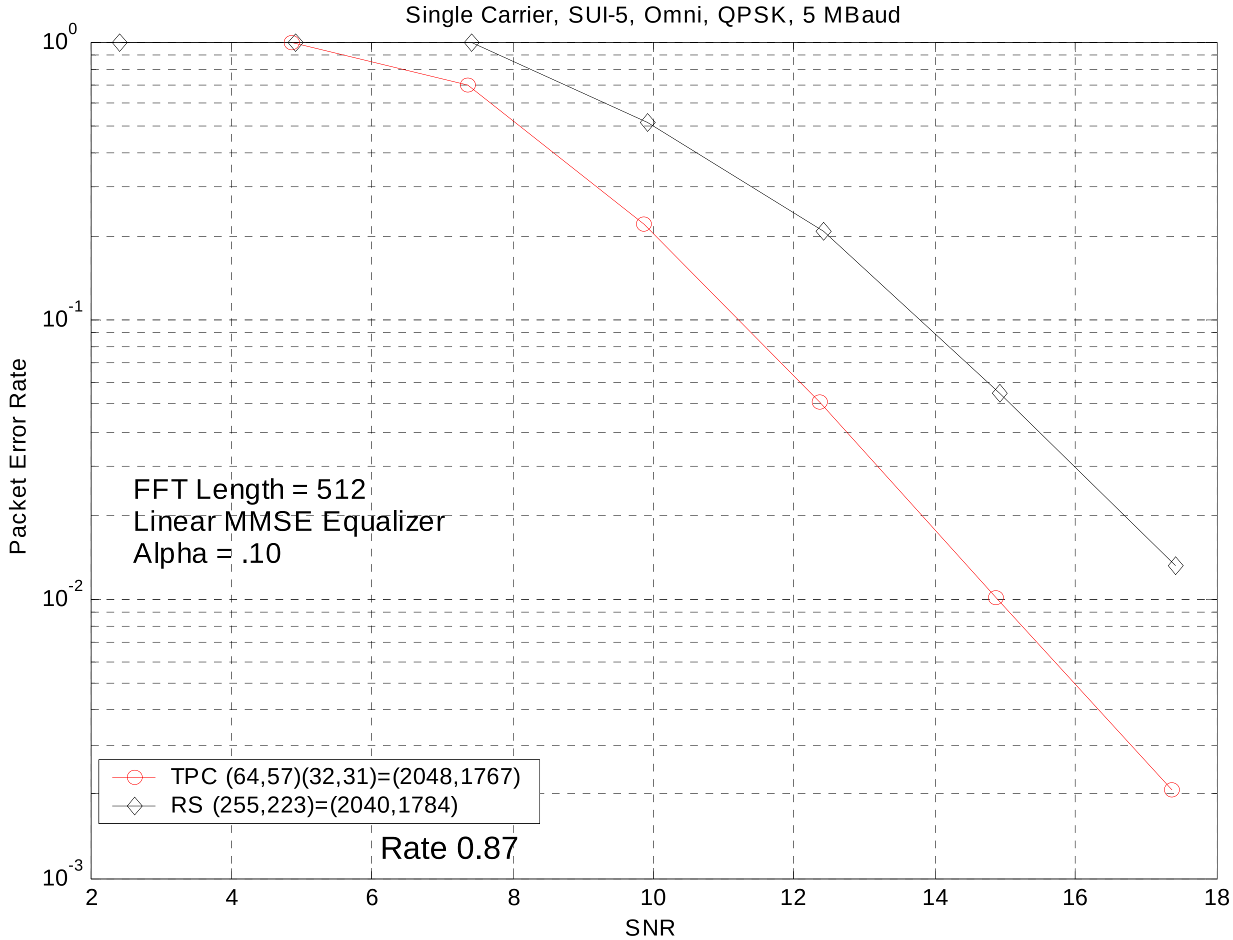
OFDM Results



Simulation Assumptions

- Monte-Carlo Simulation, based on min errors
- Modulation QPSK, 16 QAM, 64 QAM with Gray code mapping
- Channel Model SUI 5, Omni Directional
- 64, **512**, 1024, 2048 point FFT
- Zero power penalty due to overhead transmission
- Coding: Turbo Product Coding, RSV
- Optimally weighted LLR soft metric derivation for TPC
- All Simulation employ channel interleaving as per proposed OFDM 16.3 method
- 32 Tap FIR, sampled 4 samples per symbol
- Roll off factor of 0.10
- Minimum Mean Squared Error, Linear
- Perfect State Information Assumed
- Packet contains 1767 bits

SC+FDE Results



Conclusion

- TPCs are readily integrated into multicarrier frameworks
- TPCs Provide high performance combined with high spectral efficiency
- TPCs have been selected TG1 & poss. TG3
- Off the shelf chips and cores available
- TPC technology is consistent with both SS and BS target costs

Cont…

16 QAM Performance in a Rayleigh Channel