Optimization of Interleaver Parameters

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Purpose:
Supportive material for comment 178 in recirc ballot 11a: "Interleaver Parameter Change"

Optimization of Interleaver Parameters

Supportive material for comment 178 in recirc. 11a

Tal Kaitz, Naftali Chayat, Ran Yaniv

Alvarion

Overview

- Review of interleaver structure
- Problem with the case of 2 subchannels
- Simulation results
- Recommendations

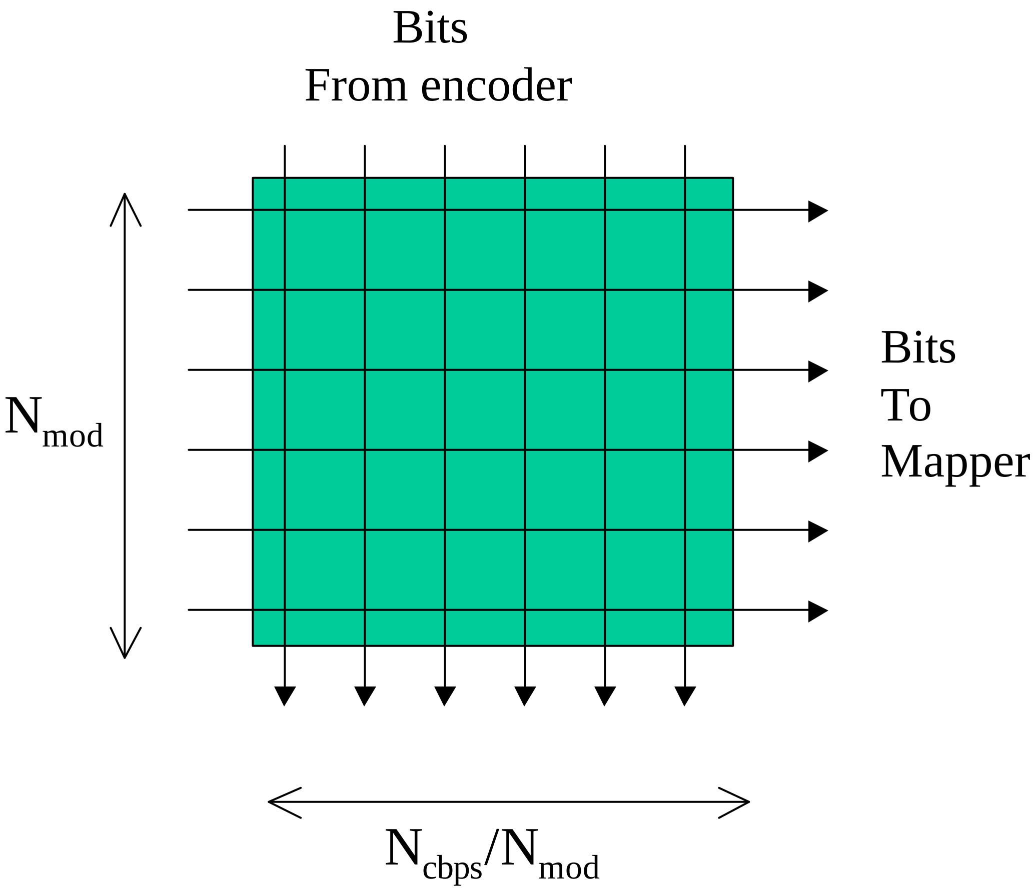
Current definition of interleaver

- Two step permutation
  - 1st permutation: “insures that adjacent bits are mapped onto non adjacent subcarriers”
  - 2nd permutation: “Avoids long runs of lowly reliable bits”

First permutation

- Matrix format
- N_{mod} x (N_{cbps}/N_{mod})
- N_{cbps} : coded bits / OFDM
- N_{mod} : Itlv parameter

- Also
- N_c: number of sub-carriers
- N_{cpc}: number of bits /sc
- $N_{cbps}=N_c*N_{cpc}$

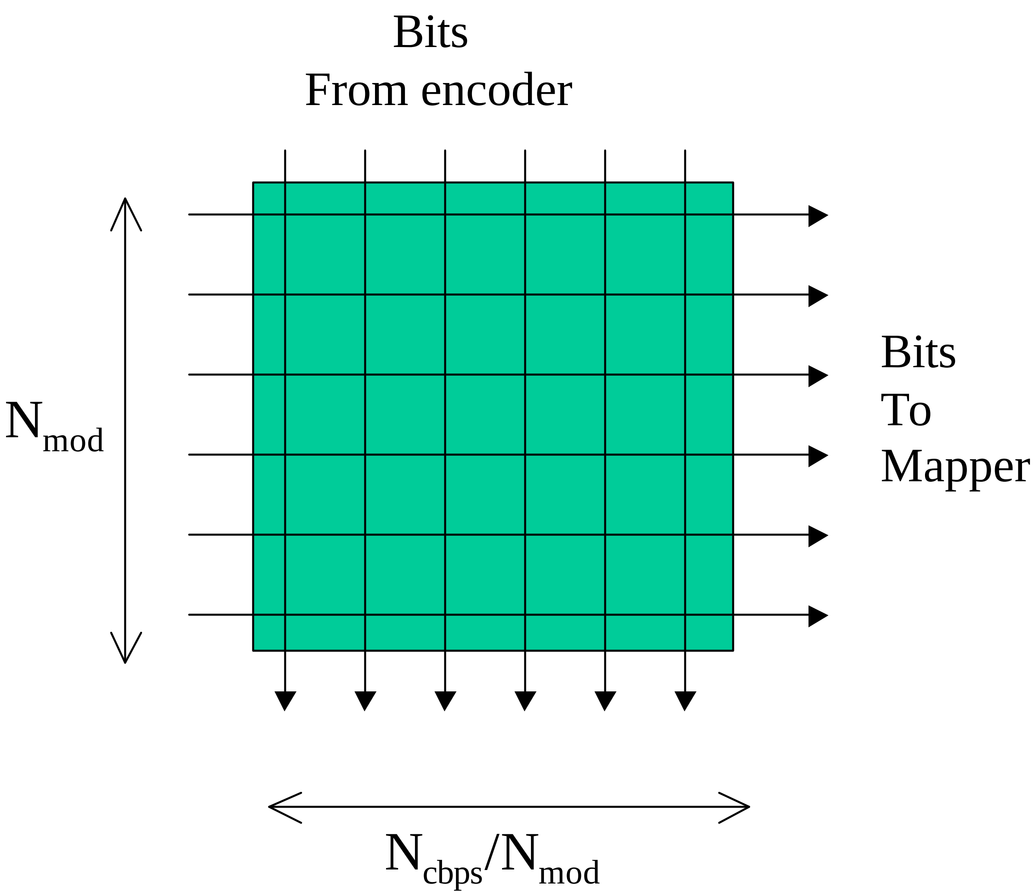


First Permutation

- Insures that
  A. Adjacent coded bits are mapped to subcarriers which are N_c/N_{mod} apart
  B. The entire bandwidth is covered in N_{mod} steps.

Second permutation

- Bit order is changed row-wise.
- Prevents run of low reliability least significant bits.
- Previous properties still hold:
  A. N_c/N_{mod} separation between adjacent coded bits
  B. BW is covered in N_{mod} steps.



Example

- QAM16 Ncpc=4
- 2 subchans Nc=24
- Nmod=12
- Write in cols
- Read out to mapper in rows

First permutation

0	12	24	36	48	60	72	84
1	13	25	37	49	61	73	85
2	14	26	38	50	62	74	86
3	15	27	39	51	63	75	87
4	16	28	40	52	64	76	88
5	17	29	41	53	65	77	89
6	18	30	42	54	66	78	90
7	19	31	43	55	67	79	91
8	20	32	44	56	68	80	92
9	21	33	45	57	69	81	93
10	22	34	46	58	70	82	94
11	23	35	47	59	71	83	95

Example: 2^{nd} permutation

- Read out to mapper in rows

0	12	24	36	48	60	72	84
13	1	37	25	61	49	85	73
2	14	26	38	50	62	74	86
15	3	39	27	63	51	87	75
4	16	28	40	52	64	76	88
17	5	41	29	65	53	89	77
6	18	30	42	54	66	78	90
19	7	43	31	67	55	91	79
8	20	32	44	56	68	80	92
21	9	45	33	69	57	93	81
10	22	34	46	58	70	82	94
23	11	47	35	71	59	95	83

Example: allocation into subcarriers

- Allocation of bits into subcarriers:
  - Format subc:bit

00:q0	02:q1	04:q0	06:q1	08:q0	10:q1	12:q0	14:q1	16:q0	18:q1	20:q0	22:q1
00:q1	02:q0	04:q1	06:q0	08:q1	10:q0	12:q1	14:q0	16:q1	18:q0	20:q1	22:q0
00:i0	02:i1	04:i0	06:i1	08:i0	10:i1	12:i0	14:i1	16:i0	18:i1	20:i0	22:i1
00:i1	02:i0	04:i1	06:i0	08:i1	10:i0	12:i1	14:i0	16:i1	18:i0	20:i1	22:i0
01:q0	03:q1	05:q0	07:q1	09:q0	11:q1	13:q0	15:q1	17:q0	19:q1	21:q0	23:q1
01:q1	03:q0	05:q1	07:q0	09:q1	11:q0	13:q1	15:q0	17:q1	19:q0	21:q1	23:q0
01:i0	03:i1	05:i0	07:i1	09:i0	11:i1	13:i0	15:i1	17:i0	19:i1	21:i0	23:i1
01:i1	03:i0	05:i1	07:i0	09:i1	11:i0	13:i1	15:i0	17:i1	19:i0	21:i1	23:i0

Interleaver partitioning

- If N_{mod} divides N_c we have a very regular structure.
- Can be broken into simple subcarrier and bit permutations.
- Simplifies H/W design and code reuse.
- With 2 subchannels N_c=24 and N_{mod}=16 so this structure is broken.

Problem with Nsubch=2.

- The resulting mapping is

00:q0 01:i1 03:q0 04:i1 06:q0 07:i1 09:q0 10:i1 12:q0 13:i1 15:q0 16:i1 18:q0 19:i1 21:q0 22:i1
00:q1 01:i0 03:q1 04:i0 06:q1 07:i0 09:q1 10:i0 12:q1 13:i0 15:q1 16:i0 18:q1 19:i0 21:q1 22:i0
00:i0 02:q1 03:i0 05:q1 06:i0 08:q1 09:i0 11:q1 12:i0 14:q1 15:i0 17:q1 18:i0 20:q1 21:i0 23:q1
00:i1 02:q0 03:i1 05:q0 06:i1 08:q0 09:i1 11:q0 12:i1 14:q0 15:i1 17:q0 18:i1 20:q0 21:i1 23:q0
01:q0 02:i1 04:q0 05:i1 07:q0 08:i1 10:q0 11:i1 13:q0 14:i1 16:q0 17:i1 19:q0 20:i1 22:q0 23:i1
01:q1 02:i0 04:q1 05:i0 07:q1 08:i0 10:q1 11:i0 13:q1 14:i0 16:q1 17:i0 19:q1 20:i0 22:q1 23:i0

- Sometimes steps of 1 sometimes steps of 2.
- Not regular and some loss of performance is expected.
- Should change $N_{mod.}$.
- What is the optimal value ?

Optimization of Interleaver parameters

- Objective: To determine the effects of N_{mod} on the interleaver performance.
- Extensive simulations were performed.
- Conditions:
  - SUI 1,2 & 3 channel, normalized to unity power- (to eliminate flat fading effects).
  - For every packet a new channel is generated.
  - 400 bytes packets
  - Known channel state information.
  - No quantization effects
  - At least 2000 packets

Results for 1 subchannel
SUI 3

Mod	rate	SNR [dB] for Pe=10^{-2} for N_{mod}=				Current N_{mod}	Best N_{mod}	Improvement
		3	6	12	16			
QPSK	½	7.5	7	8	NA	12	6	0.5
QPSK	¾	16	18	14	NA	12	12	0
QAM16	½	14	13	13.8	NA	12	6	0.8
QAM16	¾	20.5	25	20	NA	12	12	0
QAM64	2/3	22	23	22.5	NA	12	3	0.5
QAM64	¾	25.5	27	25.5	NA	12	12	0

Results for 2 subchannels SUI 3

Mod	rate	SNR [dB] for Pe=10^{-2} for N_{mod}=				Current N_{mod}	Best N_{mod}	Improvement
		3	6	12	16			
QPSK	½	8	7.2	8	8.5	16	6	1.3
QPSK	¾	14.5	18.0	13.5	14.1	16	12	0.6
QAM16	½	14.4	13.0	13.6	14.1	16	6	1.1
QAM16	¾	20.7	21.2	19.3	20.0	16	12	0.7
QAM64	2/3	22.3	22.8	21.9	21.8	16	16	0.0
QAM64	¾	27.3	27.3	25.1	25.1	16	16	0.0

Results for 2 subchannels, SUI 1 &2

Mod	rate	Chan	SNR [dB] for Pe=10^{-2} for N_{mod}=				Current N_{mod}	Best N_{mod}	Improvement
			3	6	12	16			
QPSK	½	sui2			6.2	6.6			0.4
QPSK	¾	Sui2			12.2	12.8	16	12	0.6
QAM16	½	Sui1			10.6	10.9	16	12	0.3
QAM16	¾	Sui1			15.1	15.9	16	12	0.8
QAM64	2/3	Sui2	20.7	20.7	20.1	20.3	16	12	0.2
QAM64	¾								

Results for 4 subchannels SUI 3

Mod	rate	SNR [dB] for Pe=10^{-2} for N_{mod}=				Current N_{mod}	Best N_{mod}	Improvement
		3	6	12	16			
QPSK	½	8.4	7.4	7.7	8.3	16	6	0.9
QPSK	¾							
QAM16	½	14.3	13.2	13.2	14.0	16	12	0.8
QAM16	¾							
QAM64	2/3	22.7	21.9	21.5	21.7	16	12	0.2
QAM64	¾							

Results for 4 subchannels, SUI 1 &2

Mod	rate	Chan	SNR [dB] for Pe=10^{-2} for N_{mod}=				Current N_{mod}	Best N_{mod}	Improvement
			3	6	12	16			
QPSK	½	sui2			6.2	6.2	16	16/12	0
QPSK	¾	sui2			8.0	8.3	16	12	0.3
QAM16	½								
QAM16	¾								
QAM64	2/3								
QAM64	¾								

Results for 8 subchannels SUI 3

Mod	rate	SNR [dB] for Pe=10^{-2} for N_{mod}=				Current N_{mod}	Best N_{mod}	Improvement
		3	6	12	16			
QPSK	½							
QPSK	¾							
QAM16	½	15.8	12.5	13.0	13.9	16	6	1.4
QAM16	¾							
QAM64	2/3	24.0	21.7	21.2	21.7	16	12	0.5
QAM64	¾							

Results for 8 subchannels, SUI 1 &2

Mod	rate	Chan	SNR [dB] for Pe=10^{-2} for N_{mod}=				Current N_{mod}	Best N_{mod}	Improvement
			3	6	12	16			
QPSK	½								
QPSK	¾								
QAM16	½								
QAM16	¾								
QAM64	2/3	Sui 1			18.4	18.55	16	12	0.15
QAM64	¾								

Results for 16 subchannels,

Mod	rate	Chan	SNR [dB] for Pe=10^{-2} for N_{mod}=				Current N_{mod}	Best N_{mod}	Improvement
			3	6	12	16			
QPSK	½								
QPSK	¾								
QAM16	½	Sui 3			13.4	13.4			0
QAM16	¾								
QAM64	2/3	Sui 1			18.6	18.5	16	12	0.1
QAM64	¾								

Conclusions

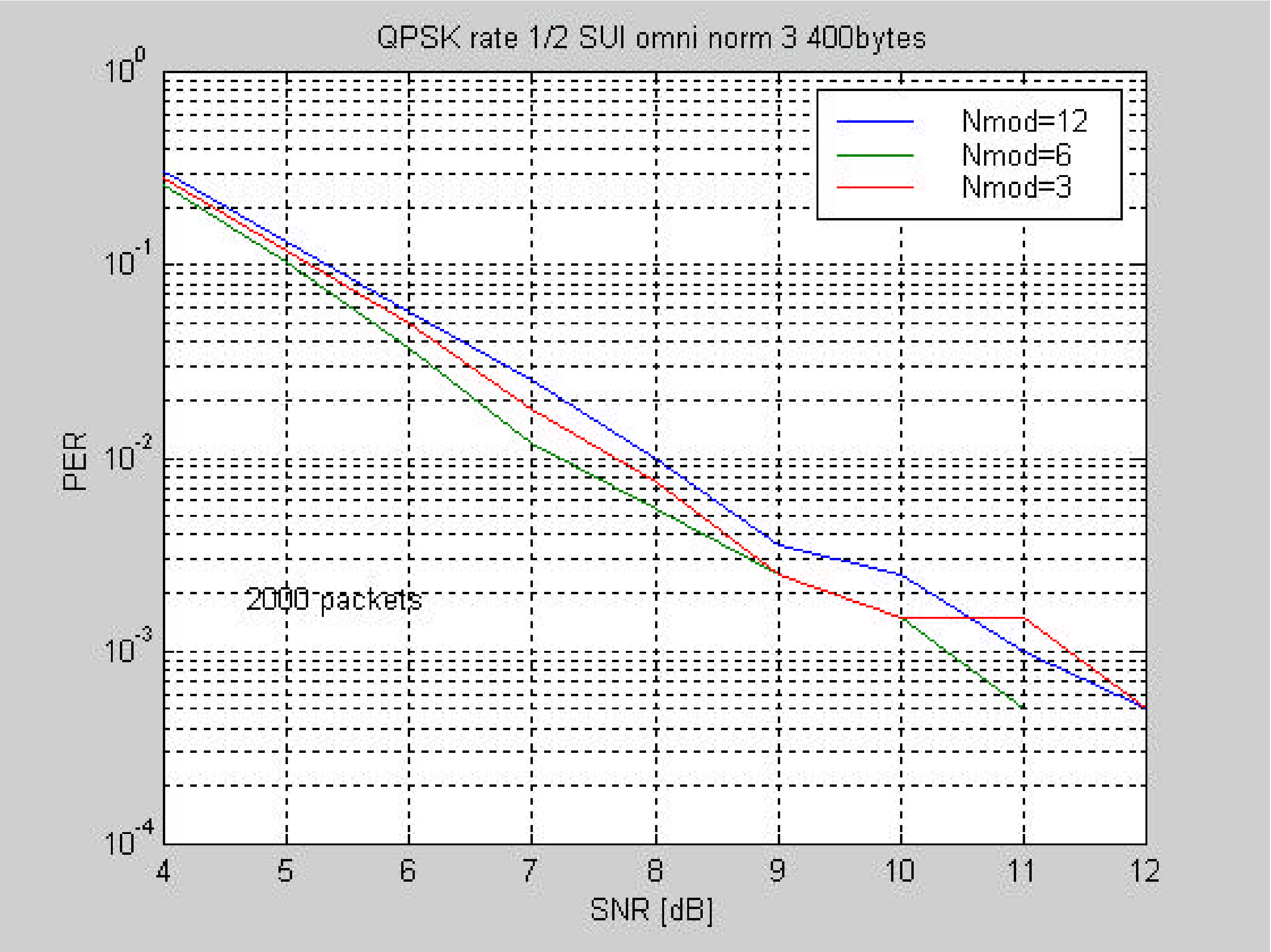
- The optimal N_{mod} depends on modulation , coding rate and number of subchannels.
- By selecting the optimal N_{mod} per case, improvements of up to 1.4dB can be achieved.
- The value on N_{mod}=12 is a good choice:
  - Slightly improve performance in all cases ~0.5dB.
  - Remove the abnormality in the case of 2 subchannels.

Recommendation

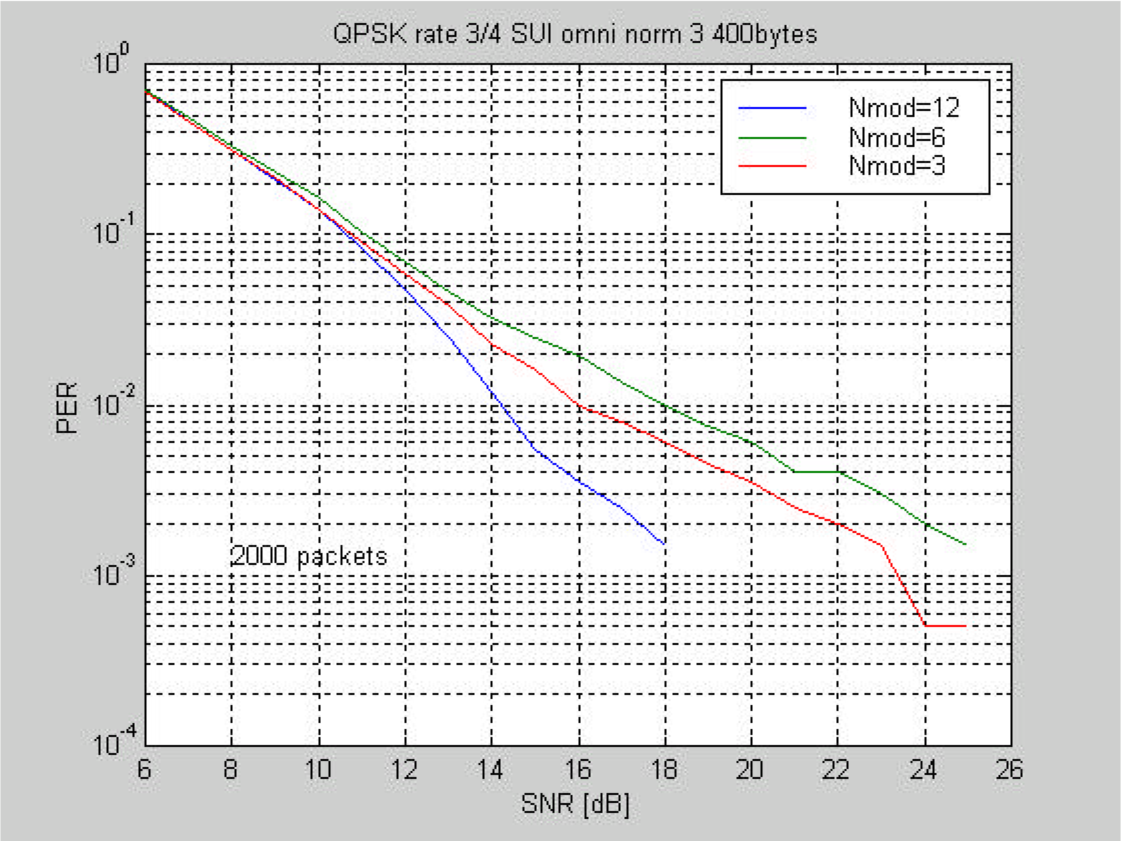
- Change the value of N_{mod} in table 116al from 16 to 12 for all cases.

Appendix: simulation results

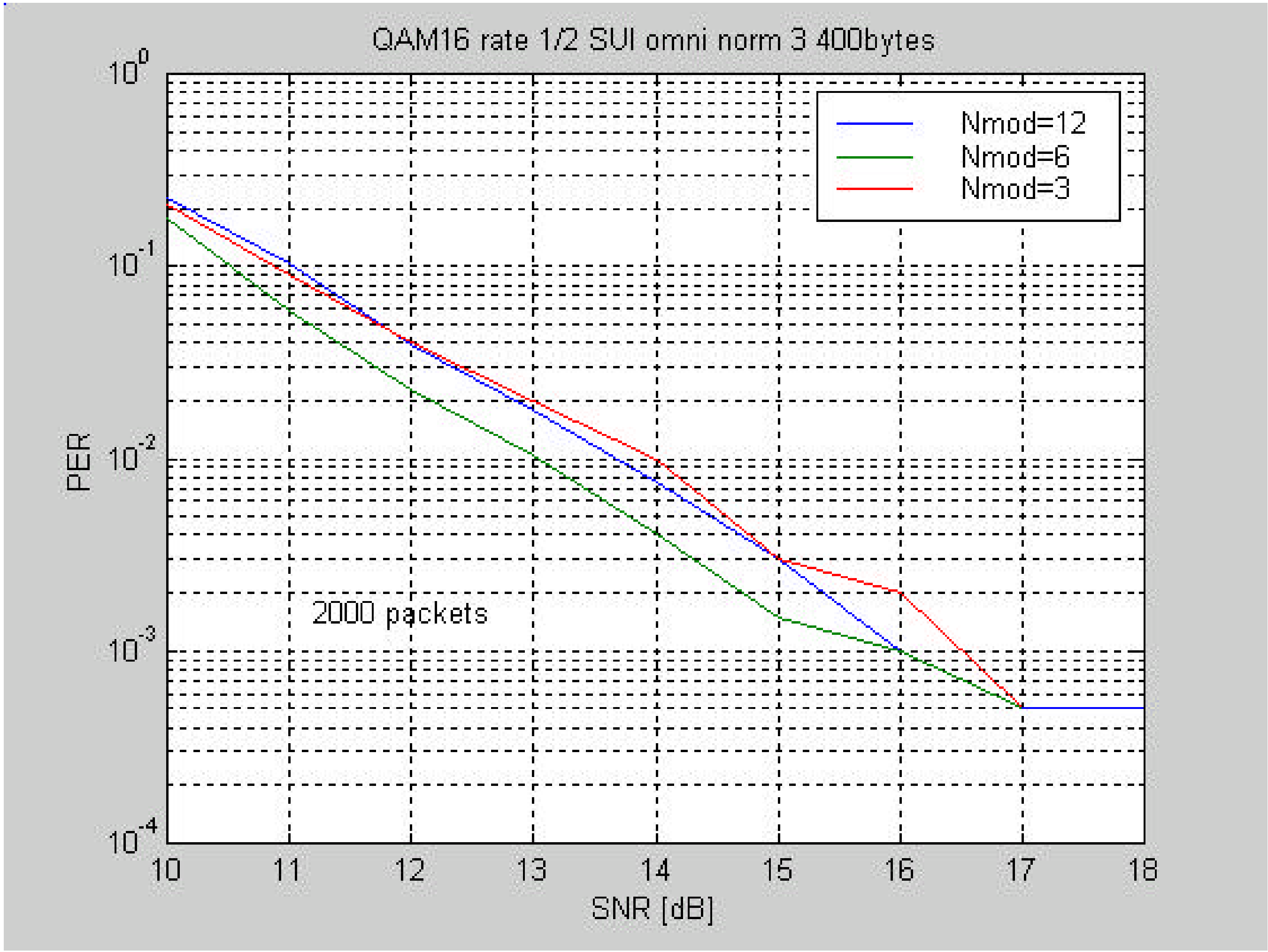
QPSK ½ 12 subc



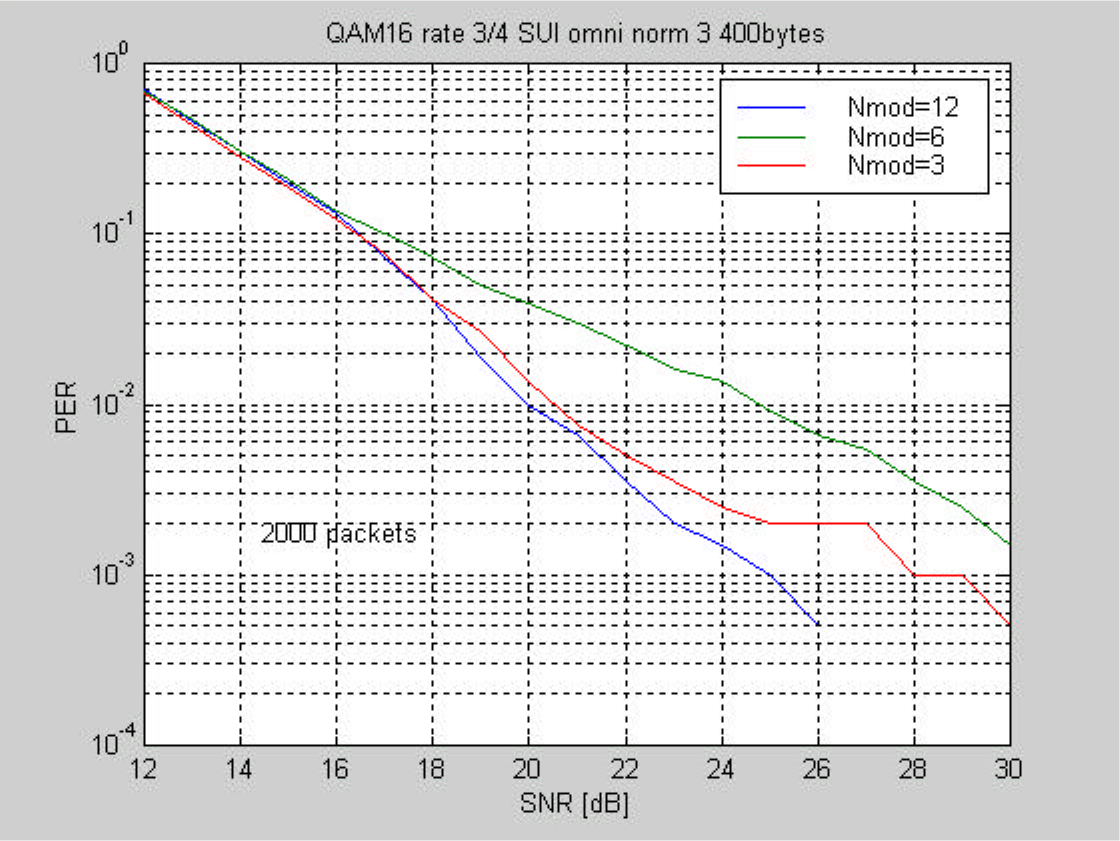
QPSK ¾ 12 subc



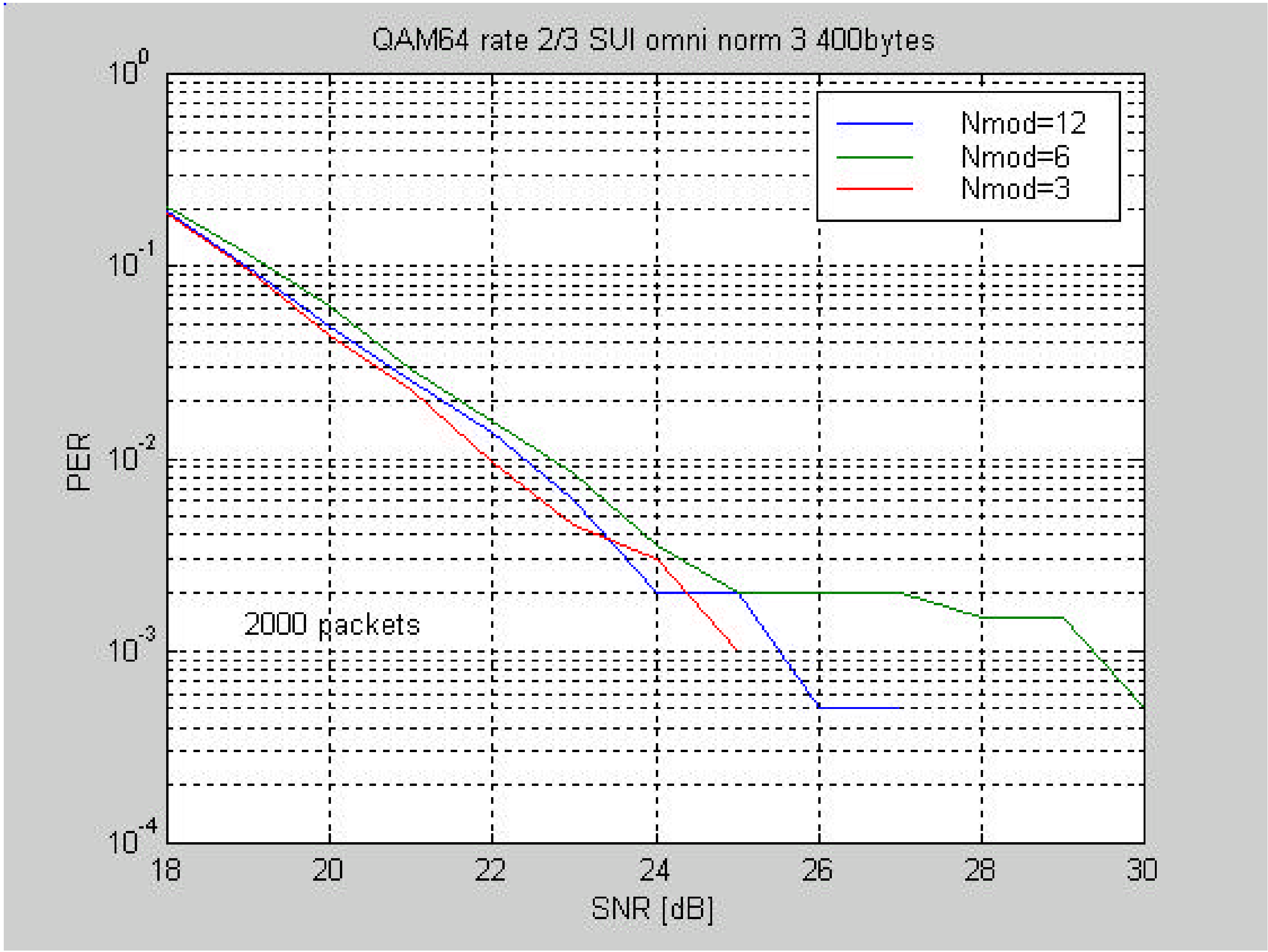
QAM 16 ½ 12 subc



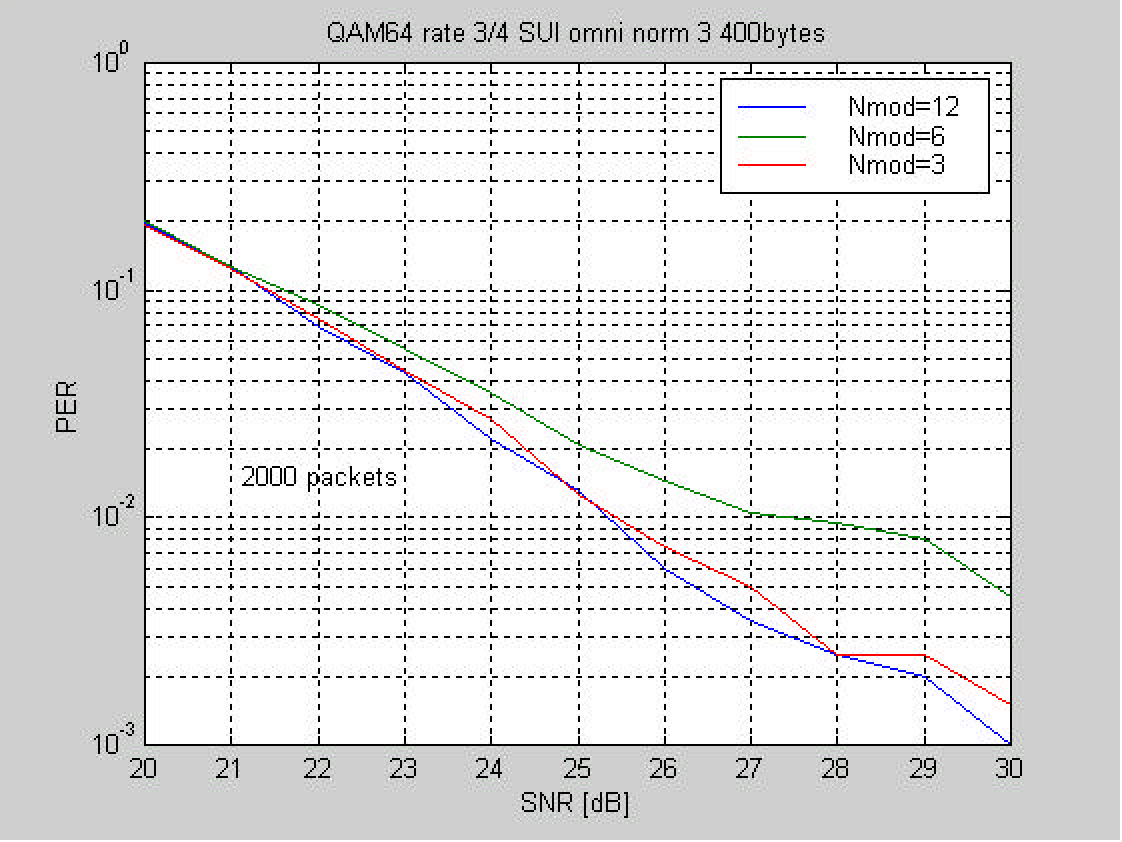
QAM16 rate ¾ 12 subc



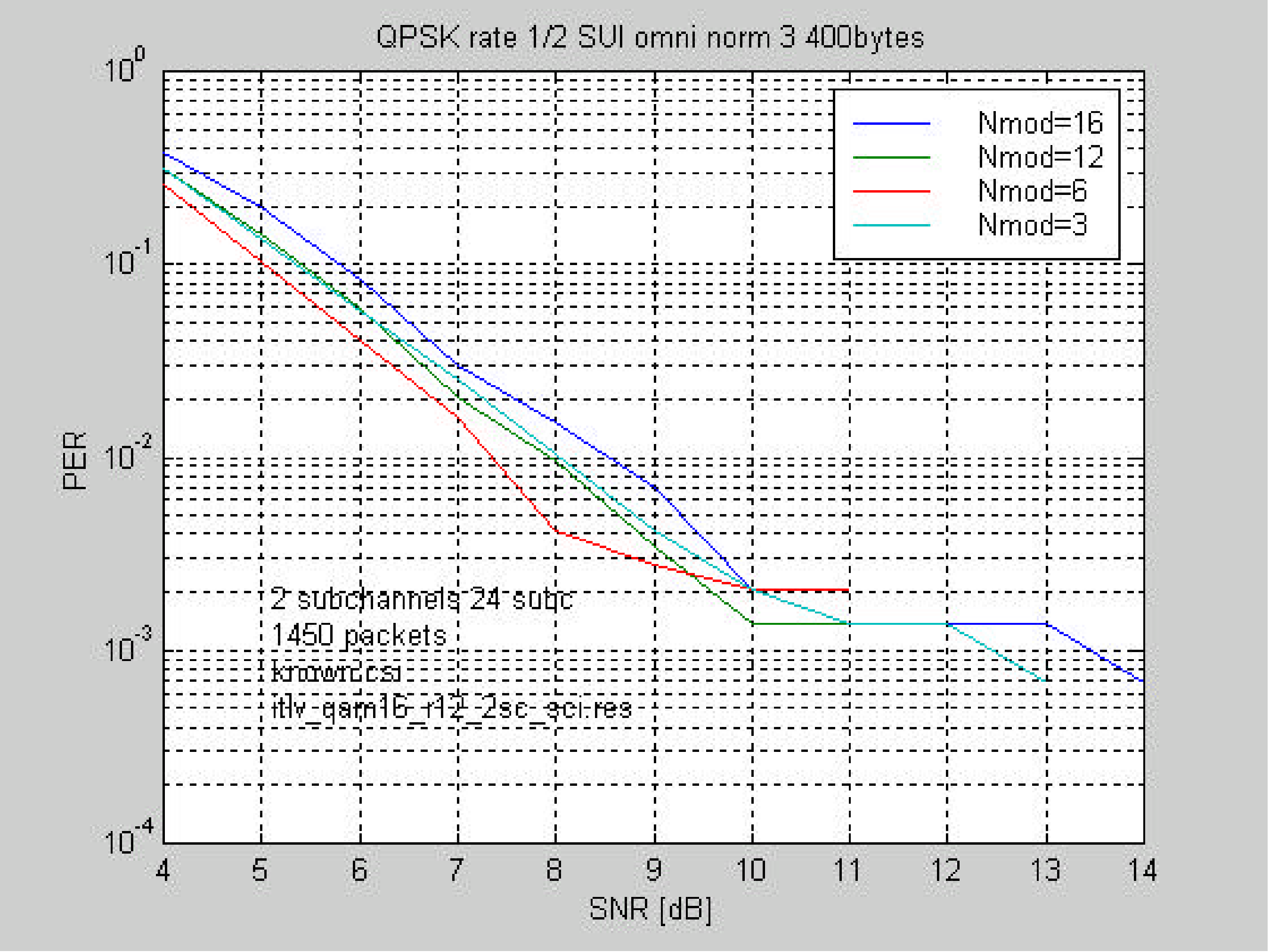
QAM64 2/3 12subc



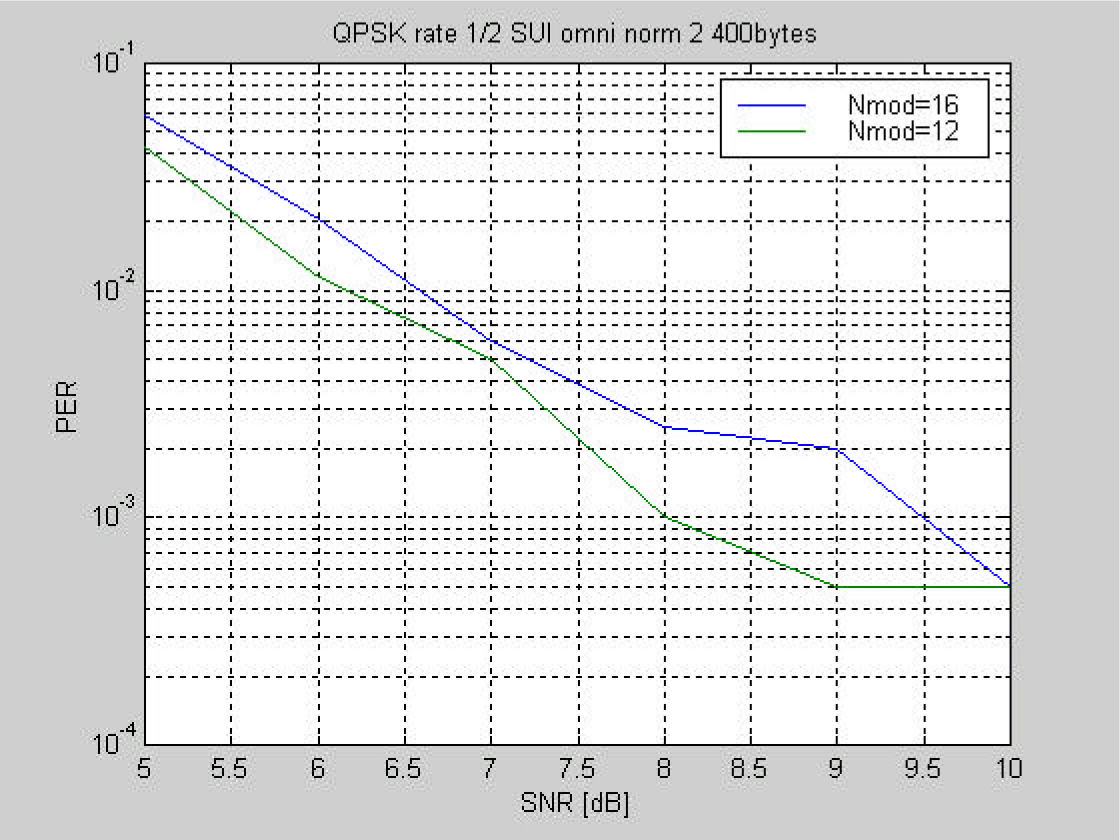
QAM64 ¾ 12 subc



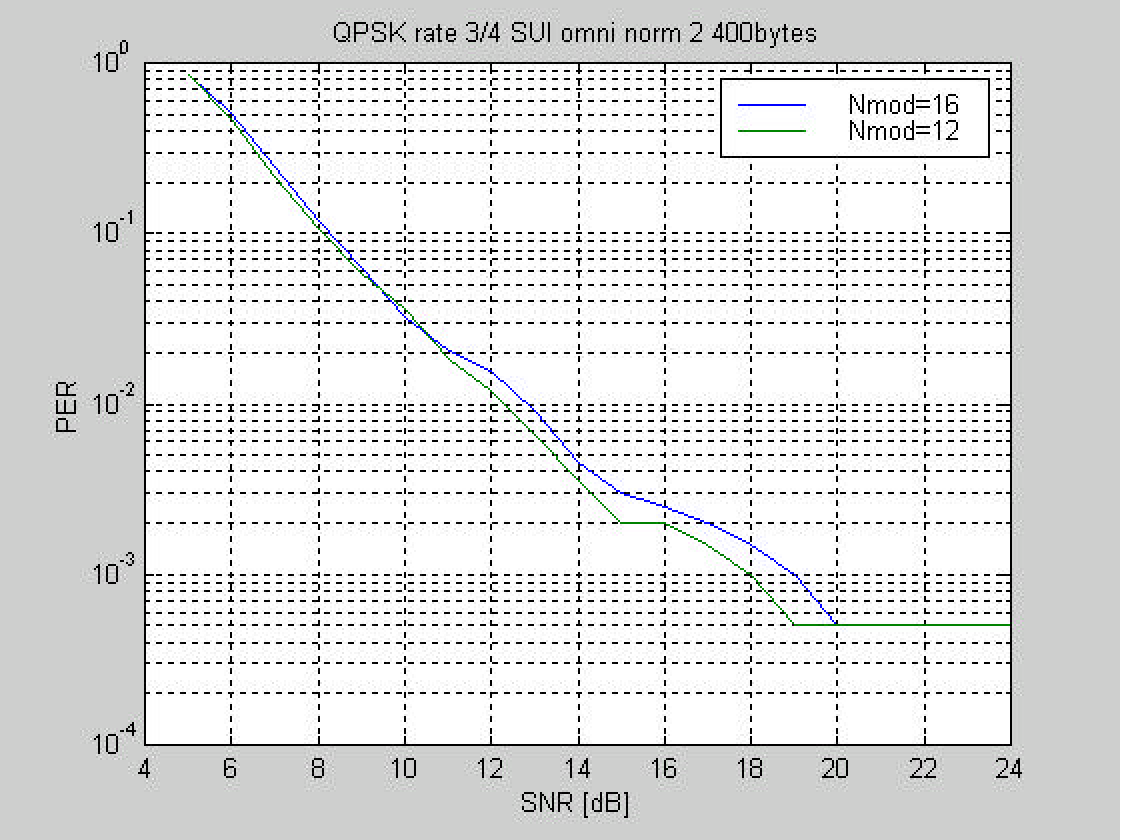
QPSK ½ 24 subc



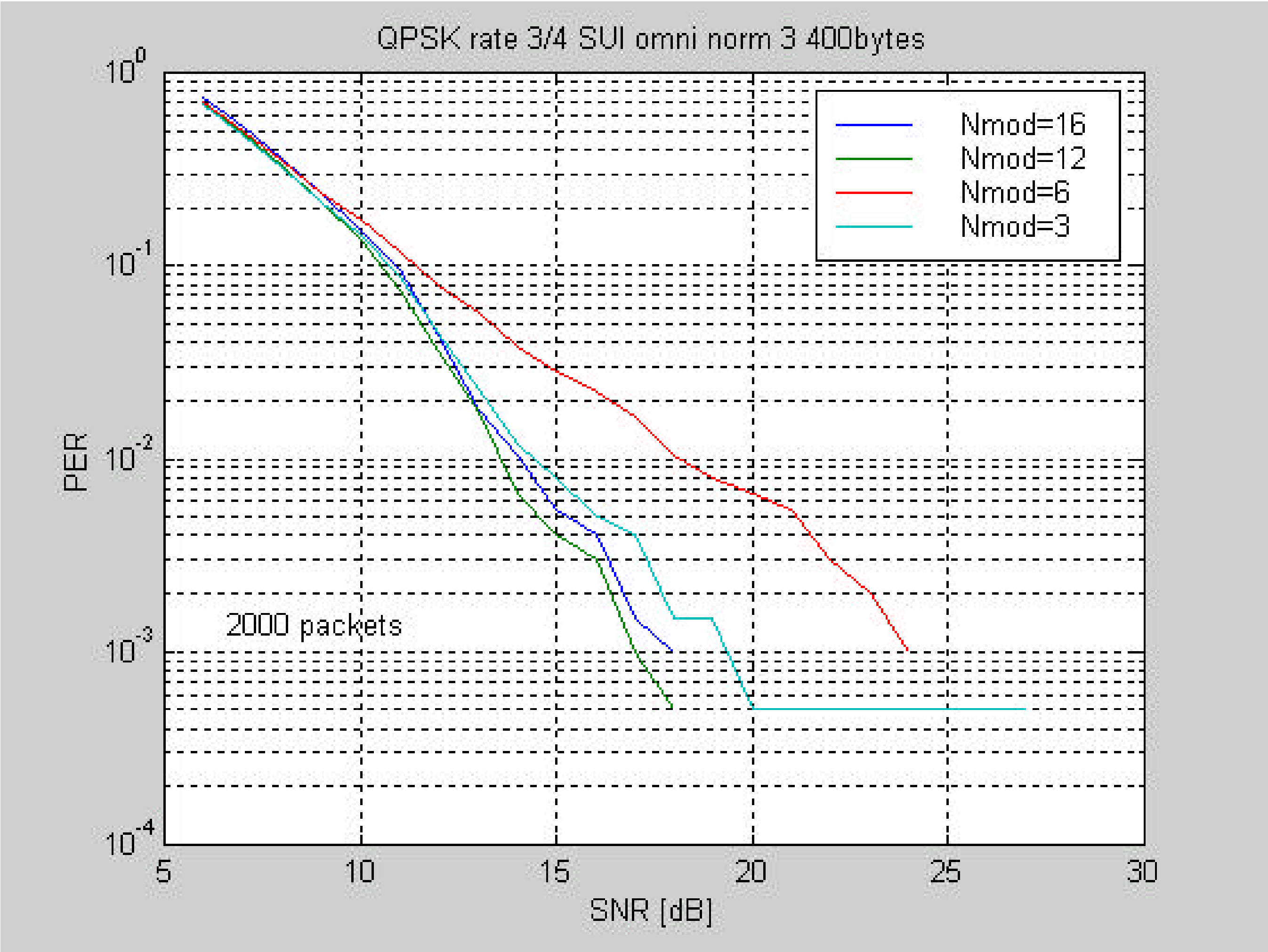
QPSK ½ 24 subc SUI2



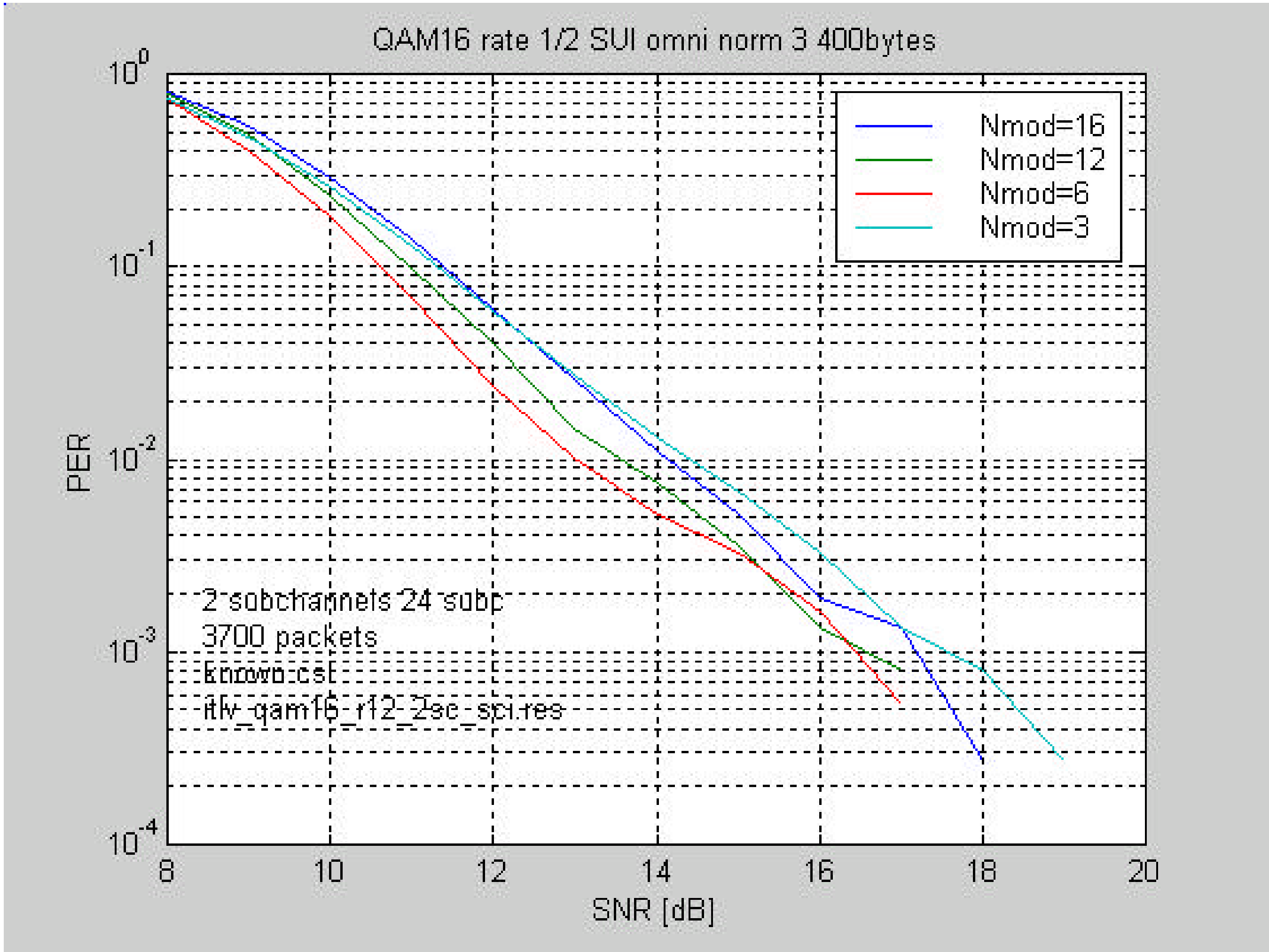
QPSK ½ 24 subc SUI 2



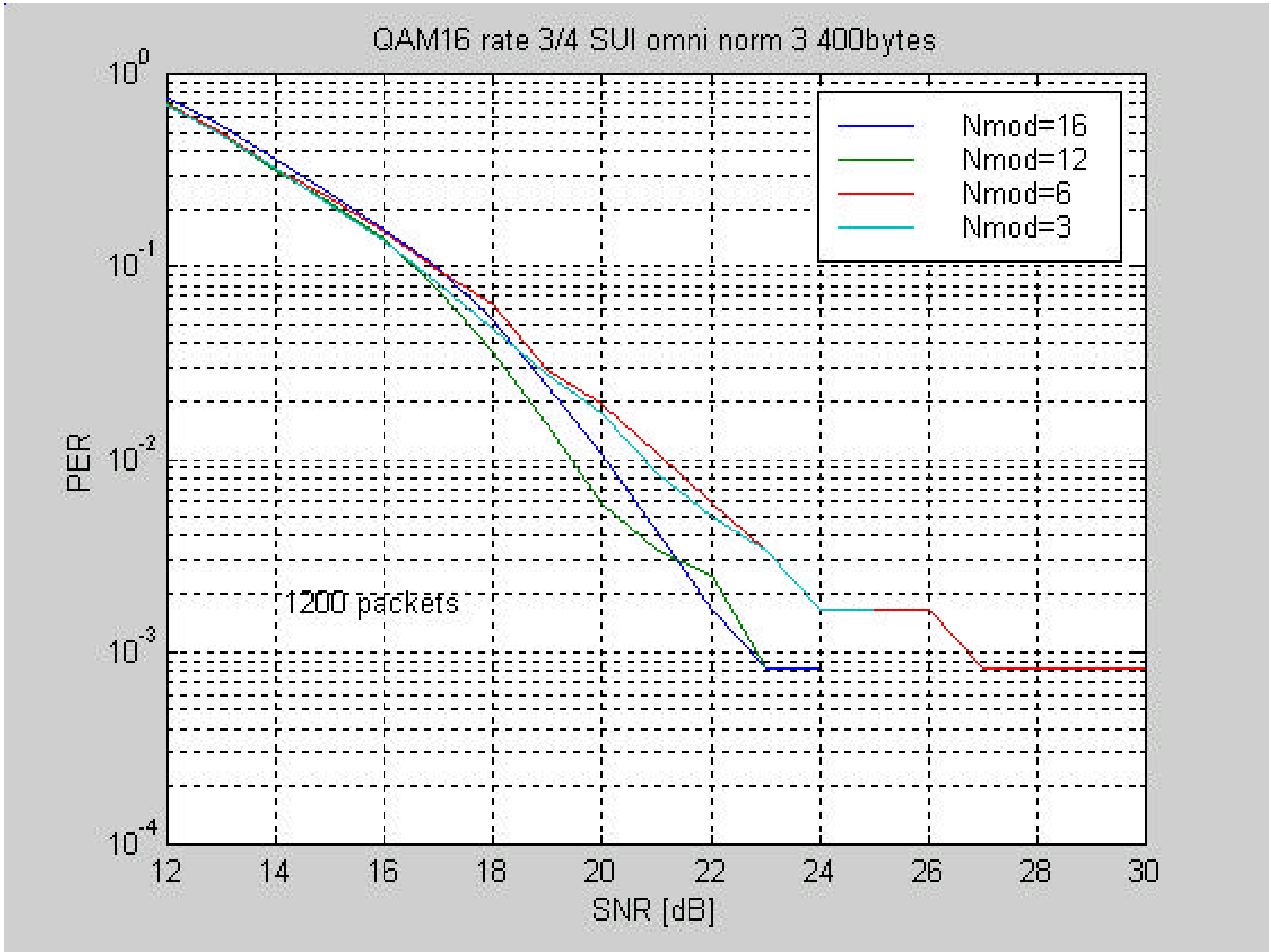
QPSK ¾ 24 subc



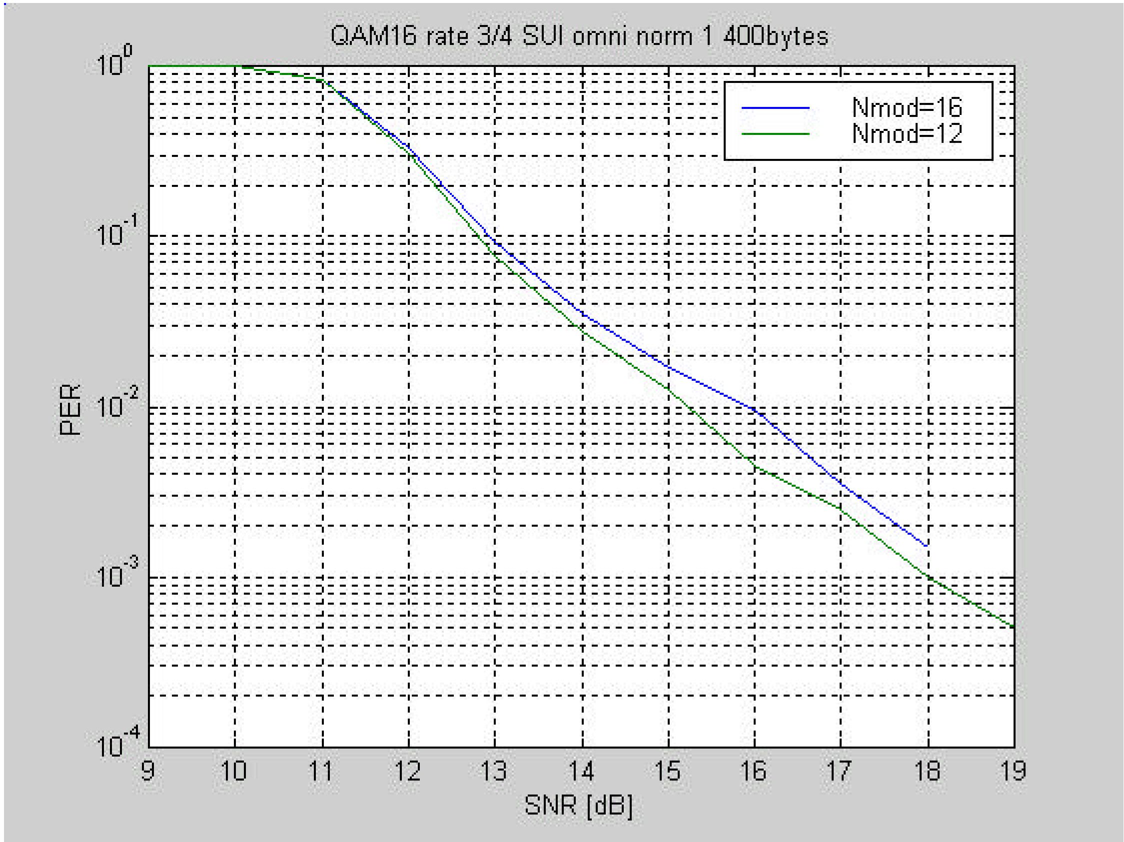
QAM16 ½ 24 subc



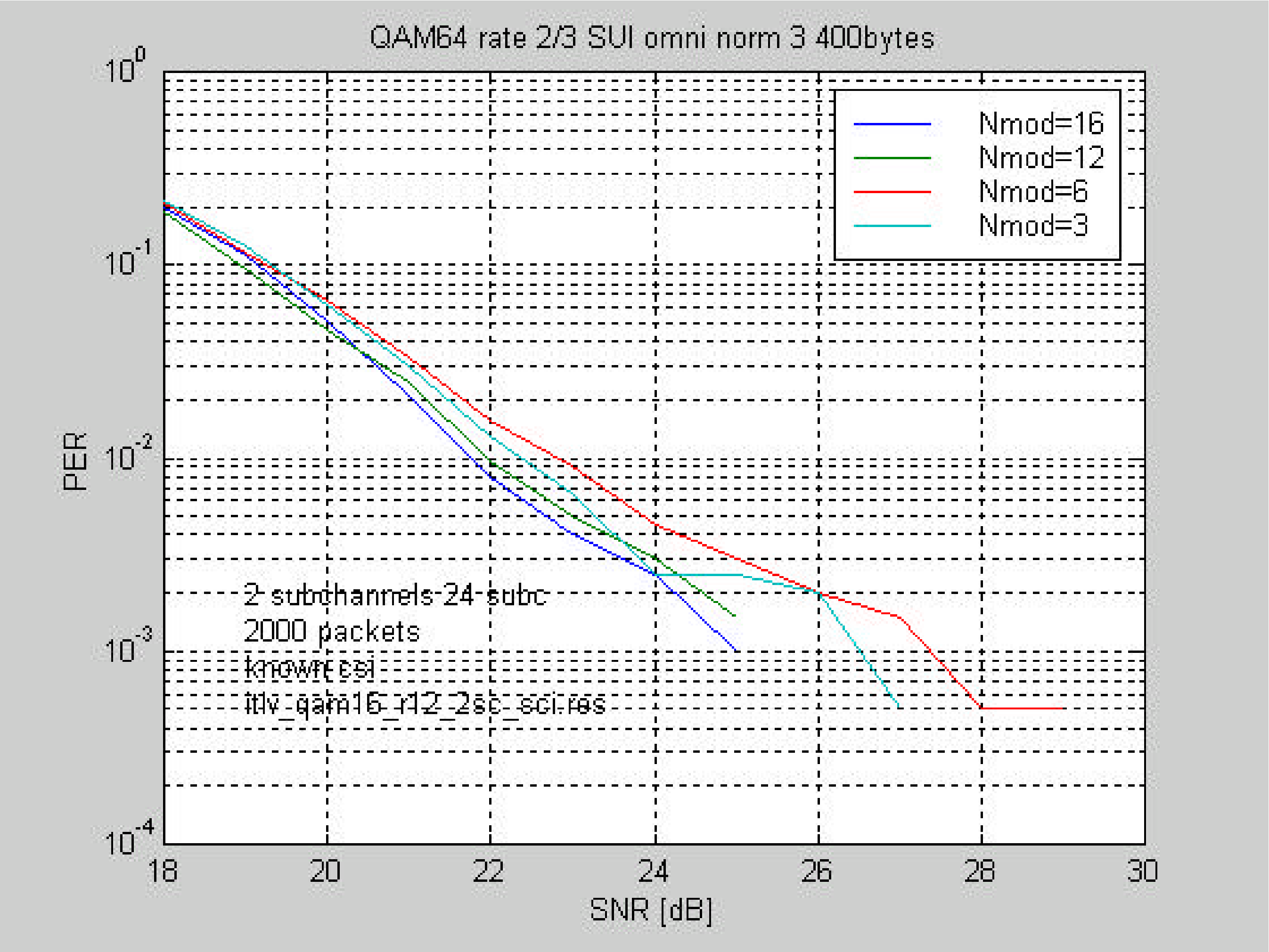
QAM16 ¾ 24 subc



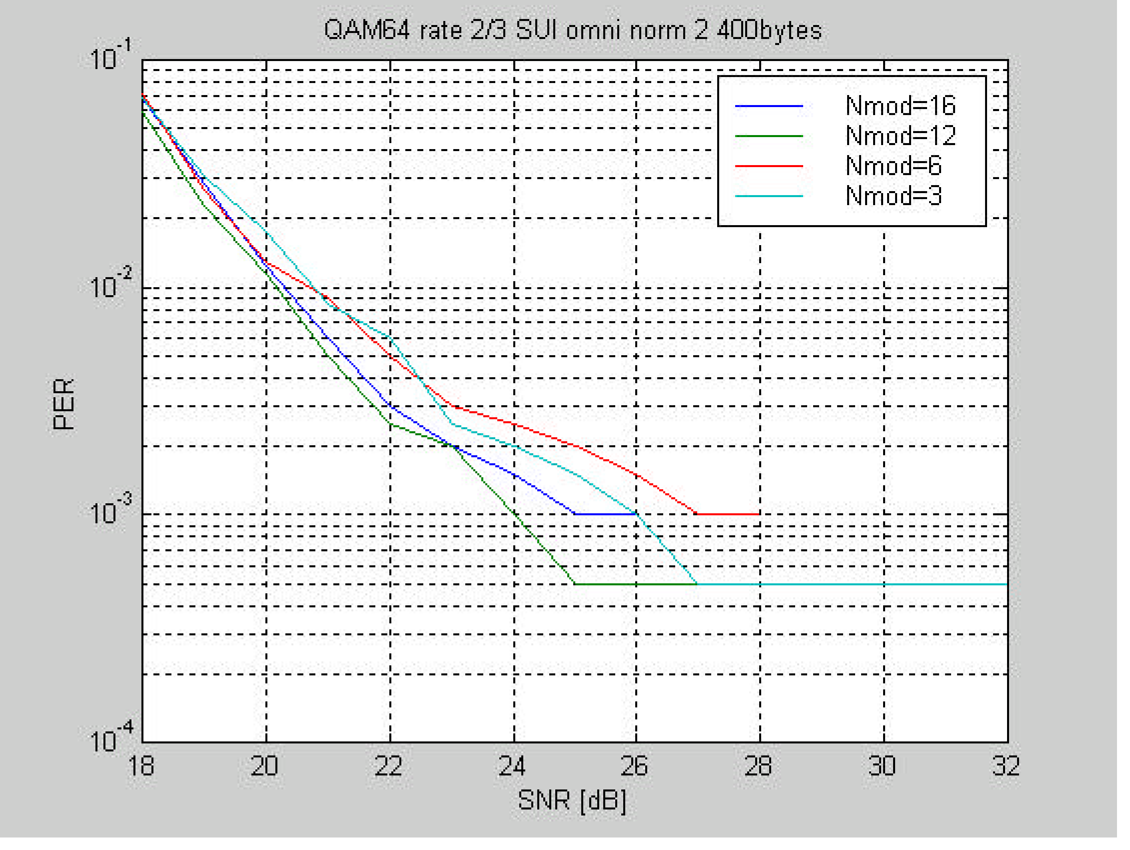
QAM16 ¾ 24 subc SUI1



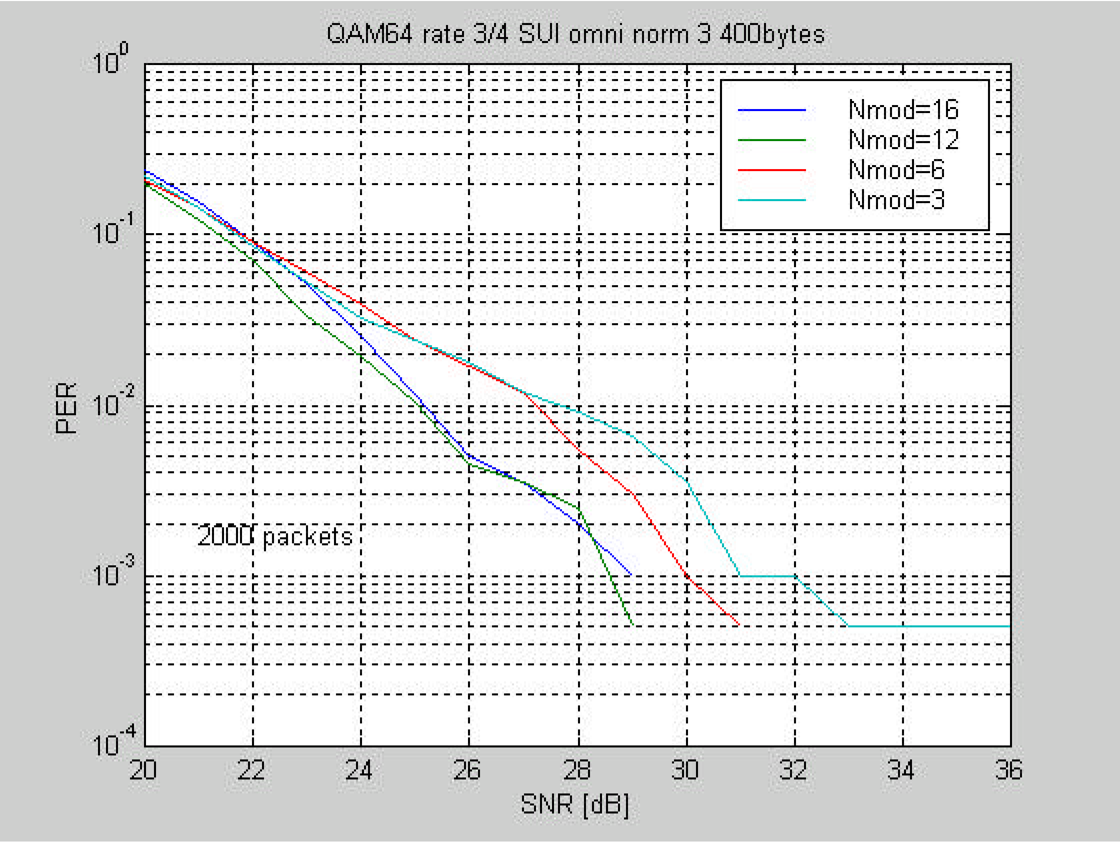
QAM64 2/3 24 subc



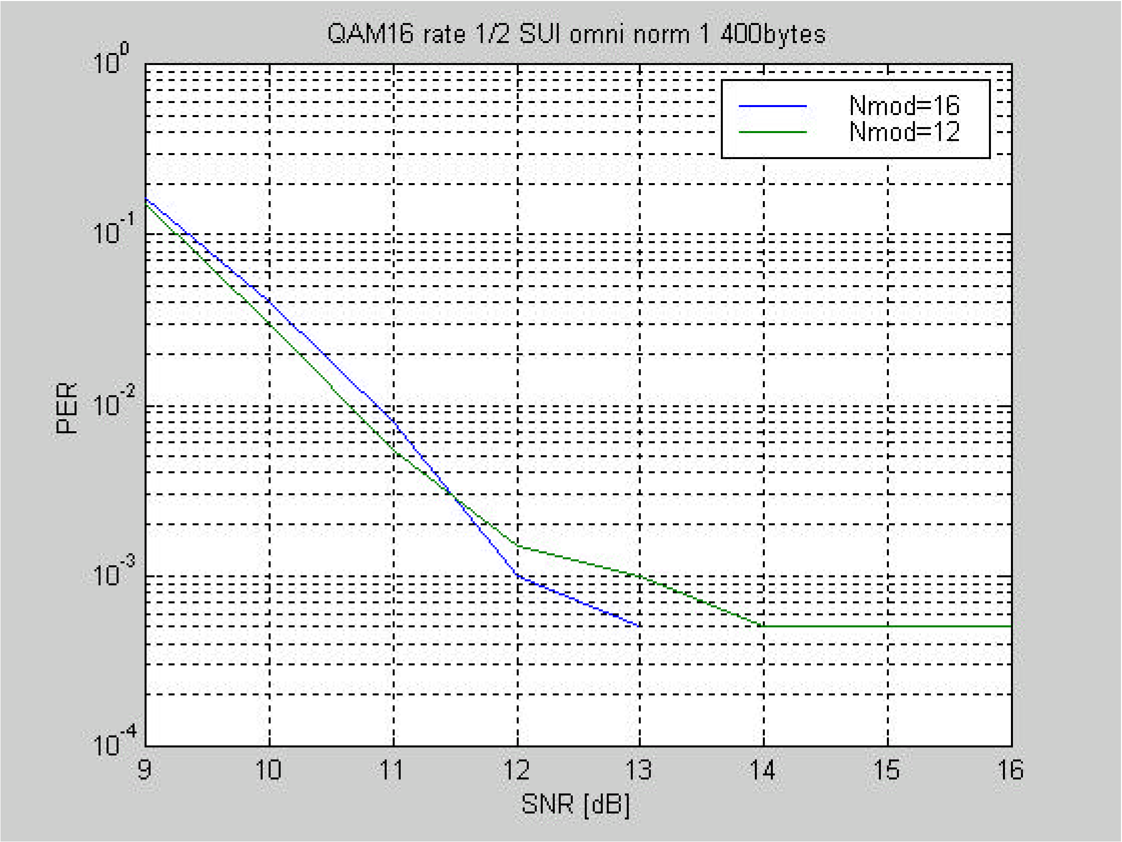
QAM64 2/3 24 subc Sui2



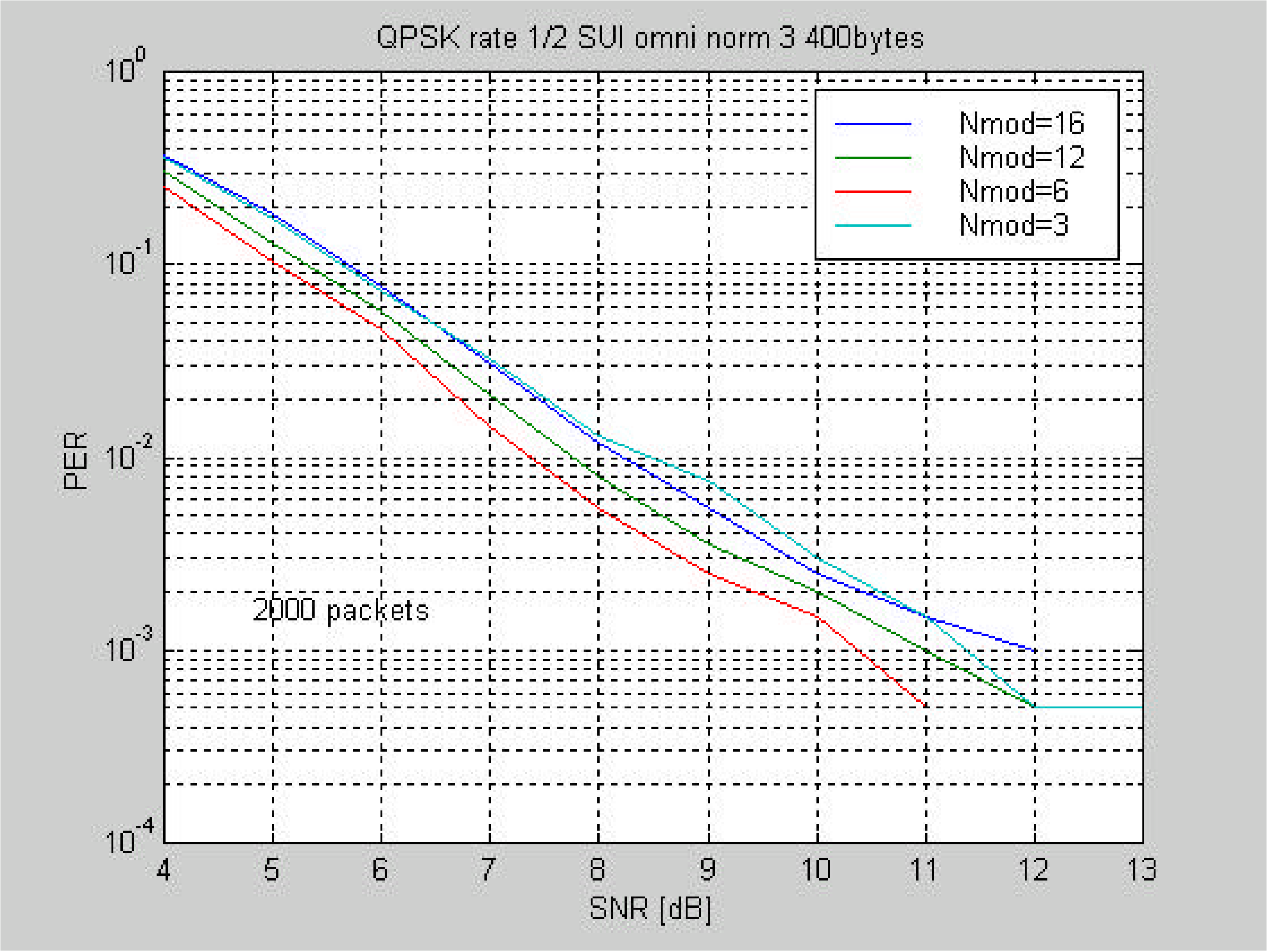
QAM64 ¾ 24 subc



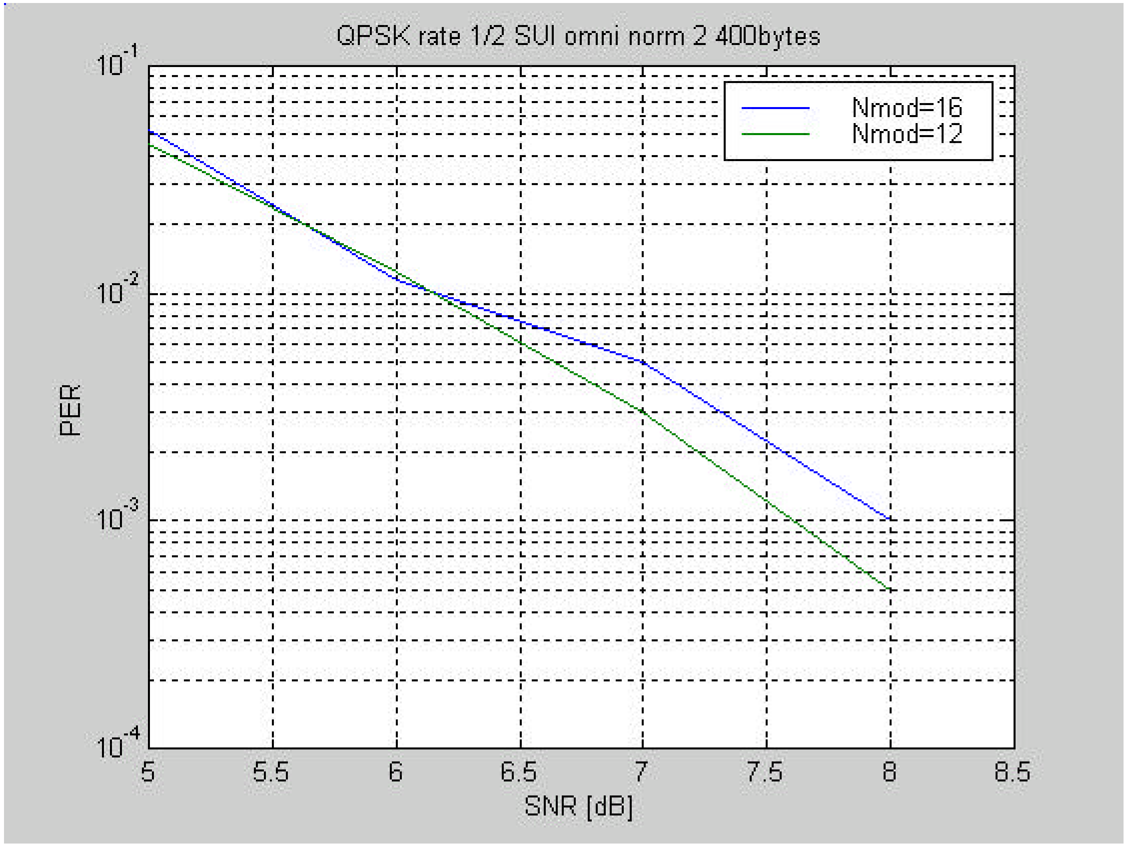
QAM16 ½ 24 subc SUI 1



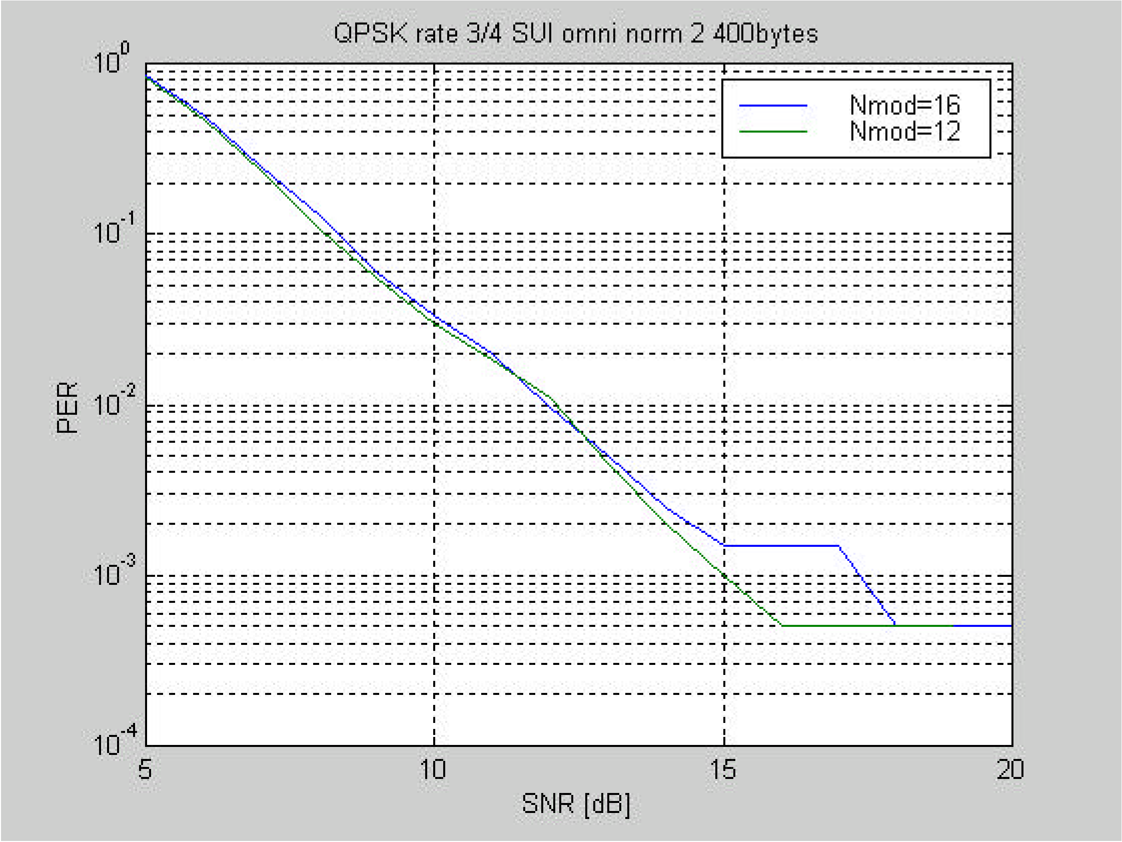
QPSK ½ 48 subc



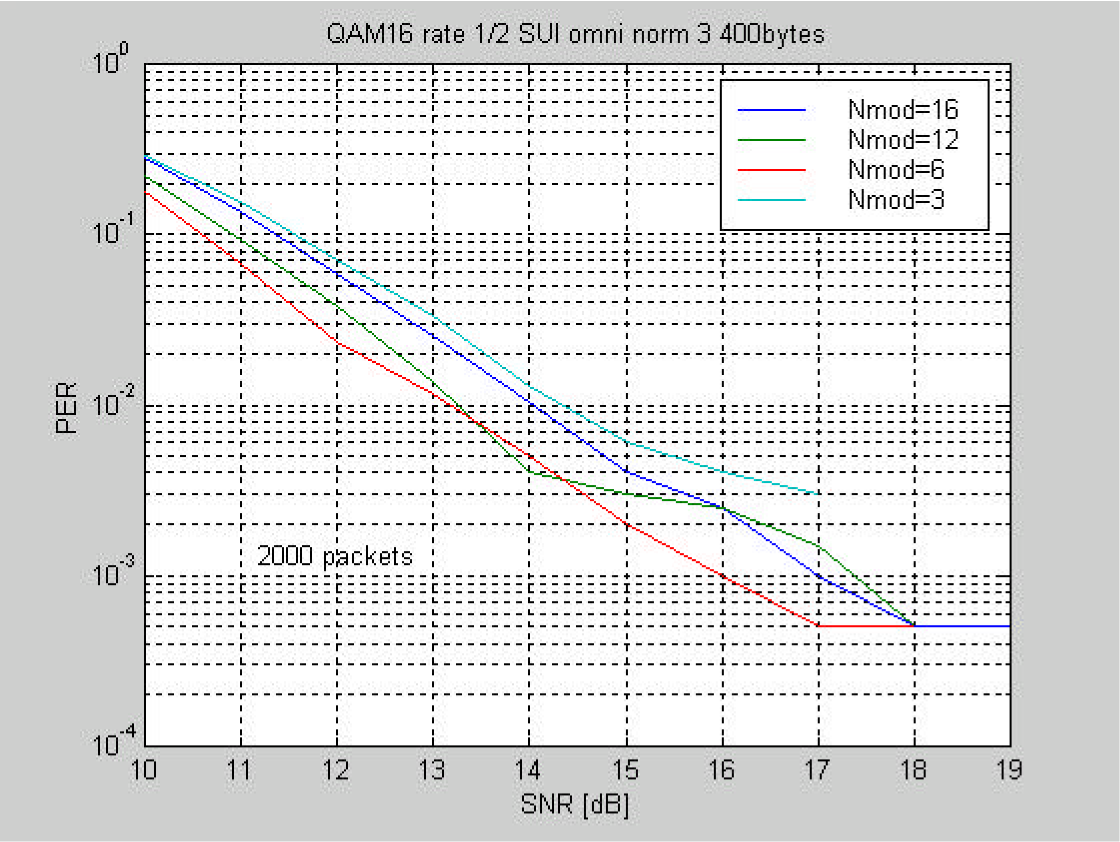
QPSK ½ 48 subc SUI 2



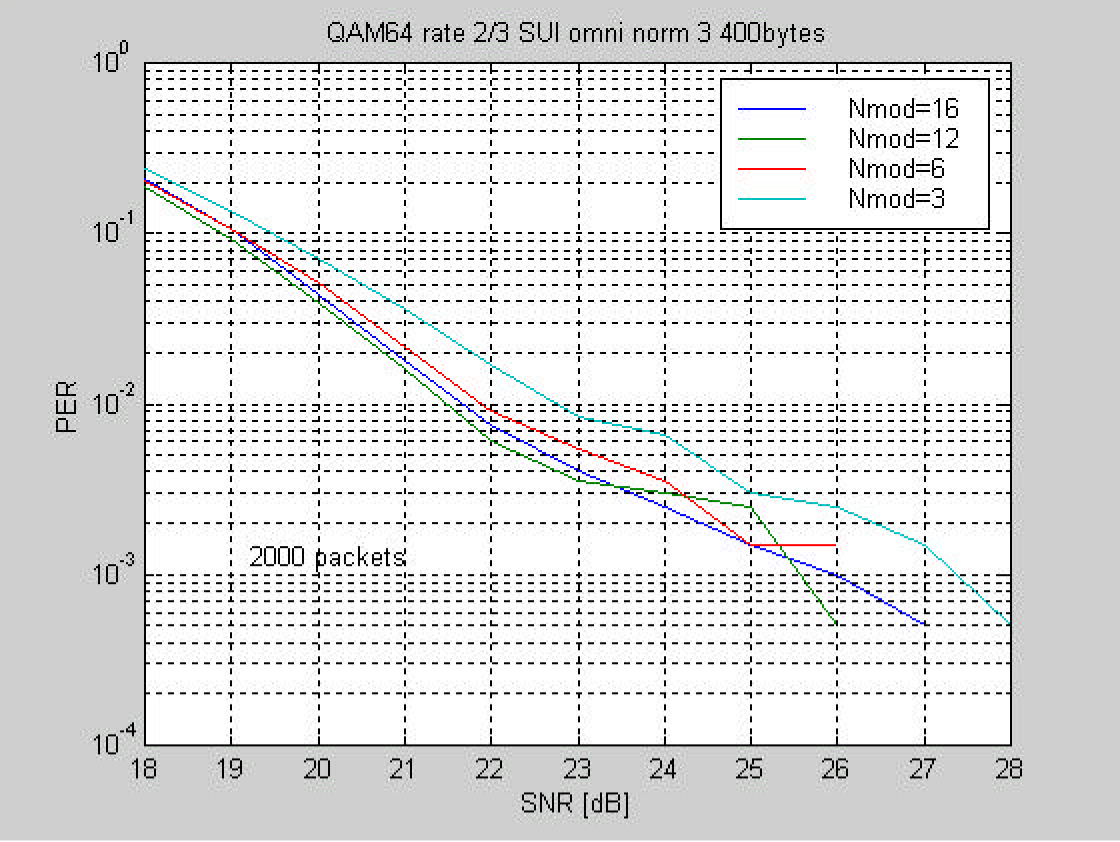
QPSK ¾ 48 subc SUI 2



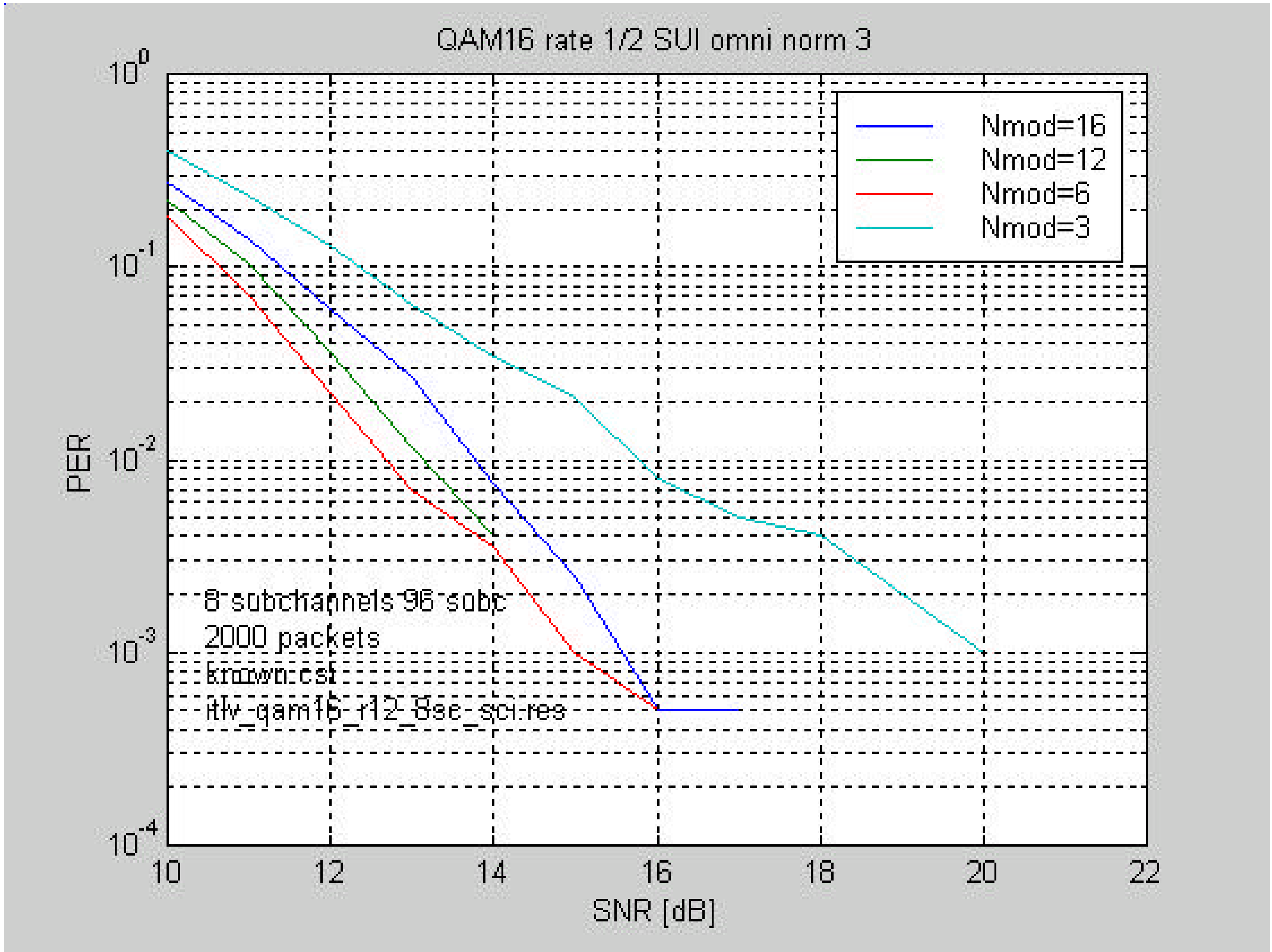
QAM16 ½ 48 subc



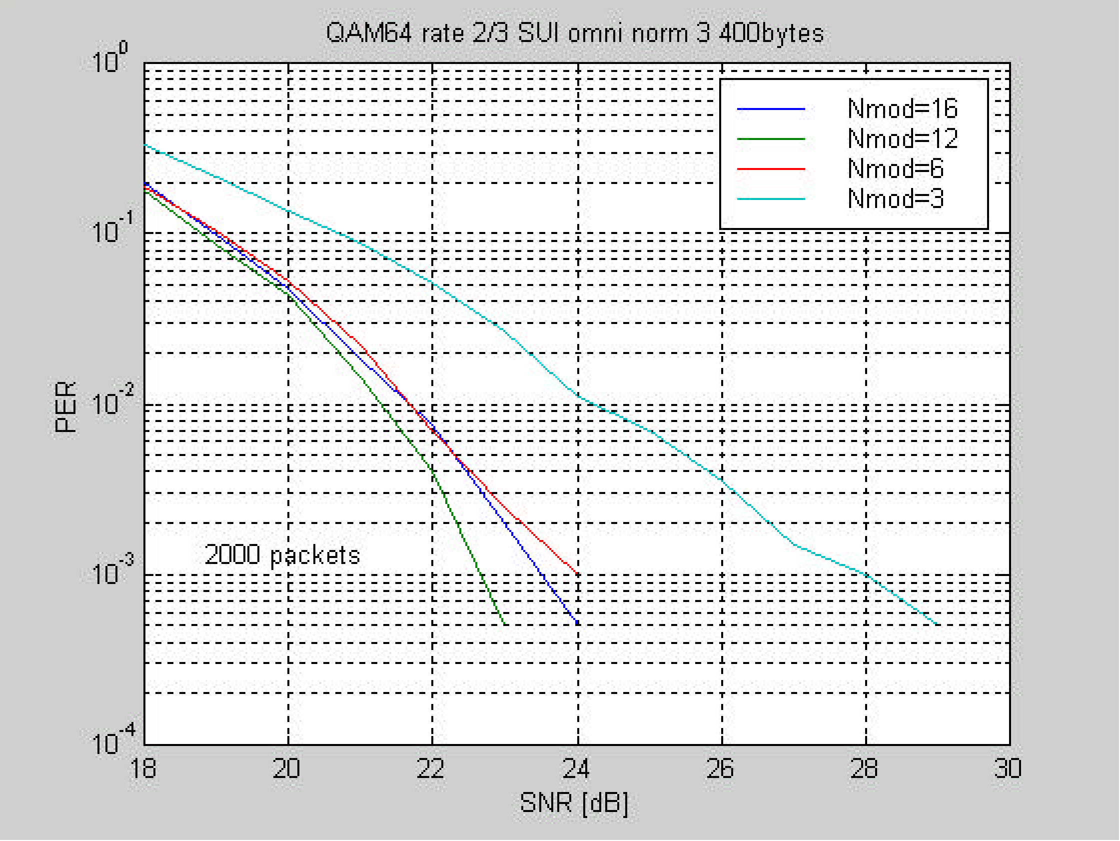
QAM64 rate 2/3 48 subc



QAM 16 1/2 96 subc



QAM64 2/3 96 subc



QAM64 2/3 96 subc SUI 1