IEEE P802.11
Wireless LANs

Raytheon Inputs to TGb proposal comparison matrix

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1.0 Introduction

This document presents a matrix of the modulation techniques being proposed by Raytheon for consideration by the TGb (high data rate 2.4GHz PHY) subgroup. The modulation technique was proposed in doc:IEEE P802.11-98/20. The basis of this matrix is the evaluation criteria described in document "97157r1.doc". The outputs of some supporting simulation and analysis are also included.

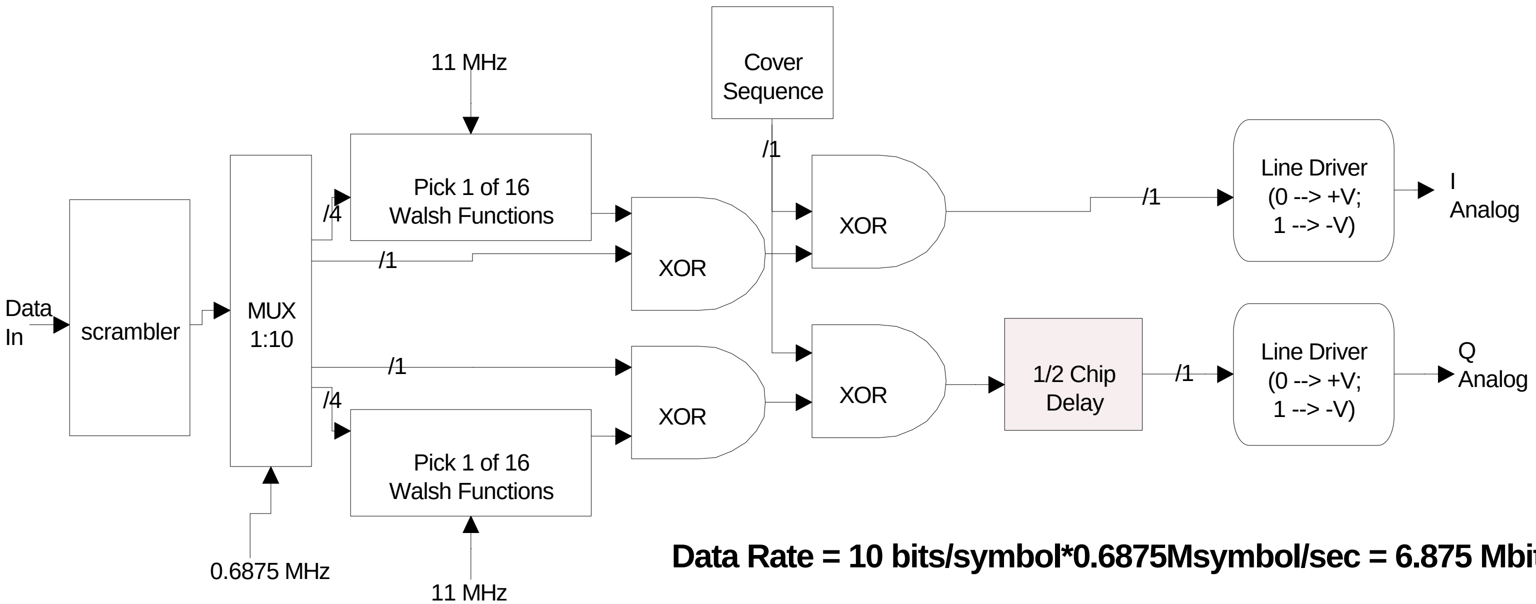
2.0 Relationship with other Proposed Waveforms

Document doc:IEEE P802.11-98/20 proposed modifications to the waveform proposed by Harris in doc:IEEE P802.11-97/144. For the Full-Rate mode Raytheon's proposal now consists of offsetting the Q channel by ½ chip period with respect to the I channel (OQPSK), maintaining a chipping rate of 11 Mchip/sec, and Walsh symbols of 8 chips each. We now also propose a "Medium-Rate" mode, using this OQPSK, still with a chipping rate of 11 Mchips/sec, but with Walsh symbols of 16 chips each. This will provide for data rates, during the packet, of 11 Mb/s for full rate, and of 6.875 Mb/s for medium-rate.

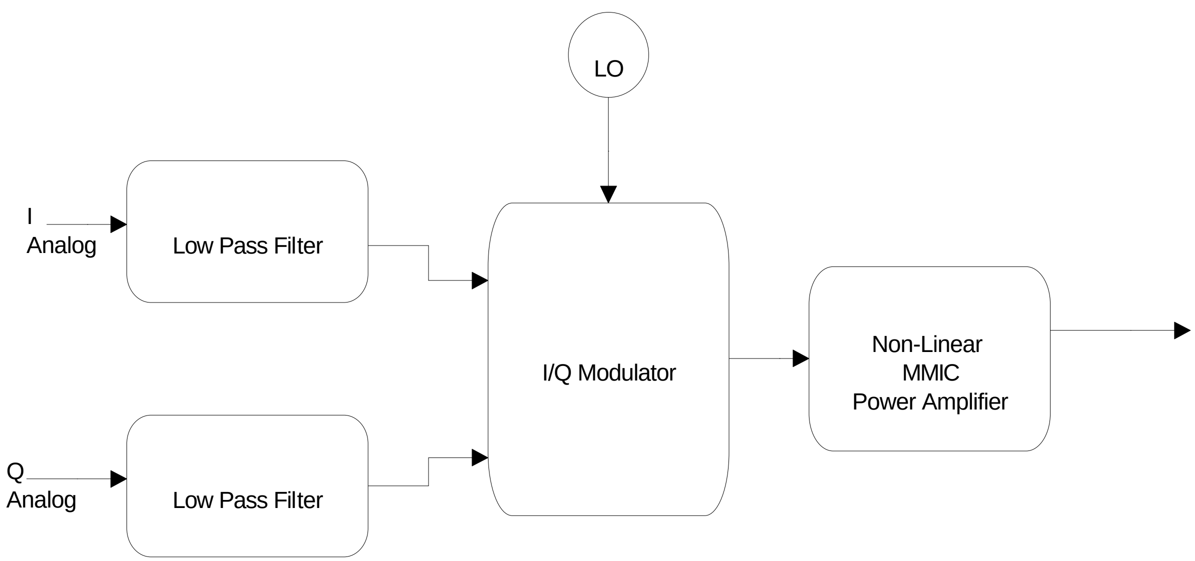
Since the waveform is a modification of that proposed in doc:IEEE P802.11-97/144, many of its parameters are the same. In that case, entries in the matrix are given as "Same as Harris Proposal." In cases where we have the results of any additional simulations or analysis available, these are included. Where absolute numbers are not known, but the difference relative to the Harris approach is, this difference (or ratio) is given, in order to provide as much information as possible.

FULL-RATE MODULATION

MEDIUM-RATE MODULATION



Data Rate = 10 bits/symbol*0.6875Msymbol/sec = 6.875 Mbit/sec



3.0 Specific Inputs for TGb proposal comparison matrix

General description:

	Raytheon
Modulation Technique	Offset Quadrature Bi-Orthogonal (OQBO)
Data Rate(s)	6.875 and 11.0 Mb/s during burst
Sensitivity	11.0 Mb/s: Same as Harris Proposal for 11 Mb/s. 6.875 Mb/s: ≈1 dB worse than Harris for proposed 5.5 Mb/s rate.
Reference submissions	doc:IEEE P802.11-98/20 doc:IEEE P802.11-98/119 doc:IEEE P802.11-98/139

Receiver structure:

	Raytheon
Receiver structure description	Same as Harris, except a ½ chip delay is added in the I channel A/D output, to compensate for the ½ chip delay inserted in the Q channel at the transmitter. For medium data rate, 16-ary, rather than 8-ary, Walsh correlations are done.
RF/IF complexity relative to current low rate PHYs.	Same as Harris.
Baseband processing complexity. relative to current low rate PHYs. (Gate Count, MIPS)	Our own independent estimates indicate a gate count of 56 kGates with no Equalization. With a simple Equalizer, this would increase to 88 kGates. This includes the logic for 16-ary Walsh generation and correlation.
Equalizer Complexity and performance impact (if applicable).	Same as Harris. Additional Data: Our own independent estimate of equalizer complexity indicates 32 kGates to implement. Performance improvement due to this equalizer is TBD.
Antenna Diversity and performance impact.	Same as Harris.

Multipath and Noise performance:

	Raytheon
Graph of PER vs. multipath rms. delay spread (no noise). Delay spread @ 10% PER for 64 and 1000 byte packets.	Same as Harris for high data rates. Our own, independent simulation of this has been done, using the model given in doc:IEEE P802.11-97/157r1, for the case of 1000 byte packets only, without diversity, without an equalizer and not including the effects of intended acquisition performance. (Figure 1.)This was for the high-data rate mode. The lowest (and only) rms. multipath delay spread (T_{RMS}) giving a PER of 10% is 31 ns.
Graph of PER vs. thermal noise w/ multipath @ 10% PER. Eb/No @ 20% PER for 64 and 1000 byte packets.	Same as Harris for high data rates. Our own, independent simulation of this has been done, using the model given in doc:IEEE802.11-97/157r1, for the case of 1000 byte packets only, without diversity, without an equalizer and not including the effects of intended acquisition performance. (Figure 2.) This was for the high-data rate mode. At the above mentioned T_{RMS} = 31ns, an E_B/N_0 = 17.3 dB gives a PER = 20%
Graph of PER vs. thermal noise (no multipath). Eb/No @ 10% PER for 64 and 1000 byte packets.	Same as Harris for high data rates. Our own, independent simulation of this has been done, using the model given in doc:IEEE802.11-97/157r1, for the case of 1000 byte packets only, without diversity, without an equalizer and not including the effects of intended acquisition performance. (Figure 3.) This was for the high-data rate mode. For this case, an E_B/N_0 = 8.9 dB gives a PER = 10%.

Carrier and Data frequency accuracy:

	Raytheon
Required Carrier frequency accuracy.	Same as Harris.
Degradation at worst case carrier frequency offset.	Same as Harris.
Data clock frequency accuracy.	Same as Harris.
Degradation at worst case data clock frequency offset.	Same as Harris.

Overhead related parameters:

	Raytheon
Preamble length	Same as Harris.
Does the preamble length include receive antenna diversity? Yes or no.	Yes. Same as Harris.
Does the preamble length include equalizer training? Yes or no.	Yes. Same as Harris.
Slot time.	Same as Harris.
CCA mechanism description.	Same as Harris.
Co-Channel signal detection time.	Same as Harris.
RX/TX turnaround time.	Same as Harris.
SIFS.	Same as Harris.

Spectral efficiency, Cell density related parameters:

	Raytheon
Channelization scheme	6.875 and 11 Mb/s: 5 MHz between allocated channel centers. 25 MHz between non-overlapping channel centers. (Same as Harris.)
Cell planing scheme	Same as Harris.
Adjacent channel interference rejection.	Same as Harris.
Co-channel interference rejection.	Same as Harris.
S/J where CW interference gives 10% PER.	Same as Harris.
Other interference immunity tests.	Same as Harris.
Co-Channel signal detection time.	Same as Harris.
Total number of channels in 2.4GHz band.	6.875 and 11 Mb/s: 13 allocated channels. 3 non-overlapping channels. (Same as Harris.)
Aggregate throughput.	11 Mb/s: Same as Harris (for 11 Mb/s mode.) 6.857 Mb/s: ≈1.25 times Harris proposal (for 5.5 Mb/s mode) due to higher rate.

Misc. critical performance factors:

	Raytheon
Phase noise sensitivity	6.875 Mb/s and 11 Mb/s: Same as Harris at 11Mb/s.
RF PA backoff	During data: Output power 1 to 2 dB below saturated output power. (See Figures 5 and 6.) During BPSK preamble: Output power 5 dB below saturated output power, or use “Offset BPSK” at 1 to 2 dB below saturated output power. (“Offset BPSK” has ≈1.5 dB degradation with respect to BPSK.)
DC power consumption	Save ≈ 0.55 W over Harris approach by using Power Amplifier with 3 dB less saturated output power. Use ≈ 0.15 W more than Harris approach with 16-ary, rather than 8-ary Walsh. Net savings of 0.40 W. If the entire card uses 2 W, this represents a saving of ≈ 20 %.

Intellectual property:

	Raytheon
Has the submission of the required IEEE letter covering IP been made? Yes or No	Yes.
Applicable patent numbers	None.
Point of contact	Mr. Richard Winer; RAYTHEON COMPANY Tel: (978) 470-9510 358 Lowell Street; Andover MA; 01810

Interoperability and Coexistence:

	Raytheon
Interoperability / Co-existence strategy with current low rate PHYs	Same as Harris.
Is the proposal Interoperable at the data level?	Same as Harris.
Is the proposal Interoperable at the antenna level?	Same as Harris.
Performance penalty due to Interoperability / Coexistence.	Same as Harris.

4.0 Supporting Simulation and Analysis Results

Multipath results are for the model given in doc:IEEE P802.11-97/157r1, for the case of 1000 byte packets only, without diversity, without an equalizer and not including the effects of intended acquisition performance, for the 11 Mb/s mode.

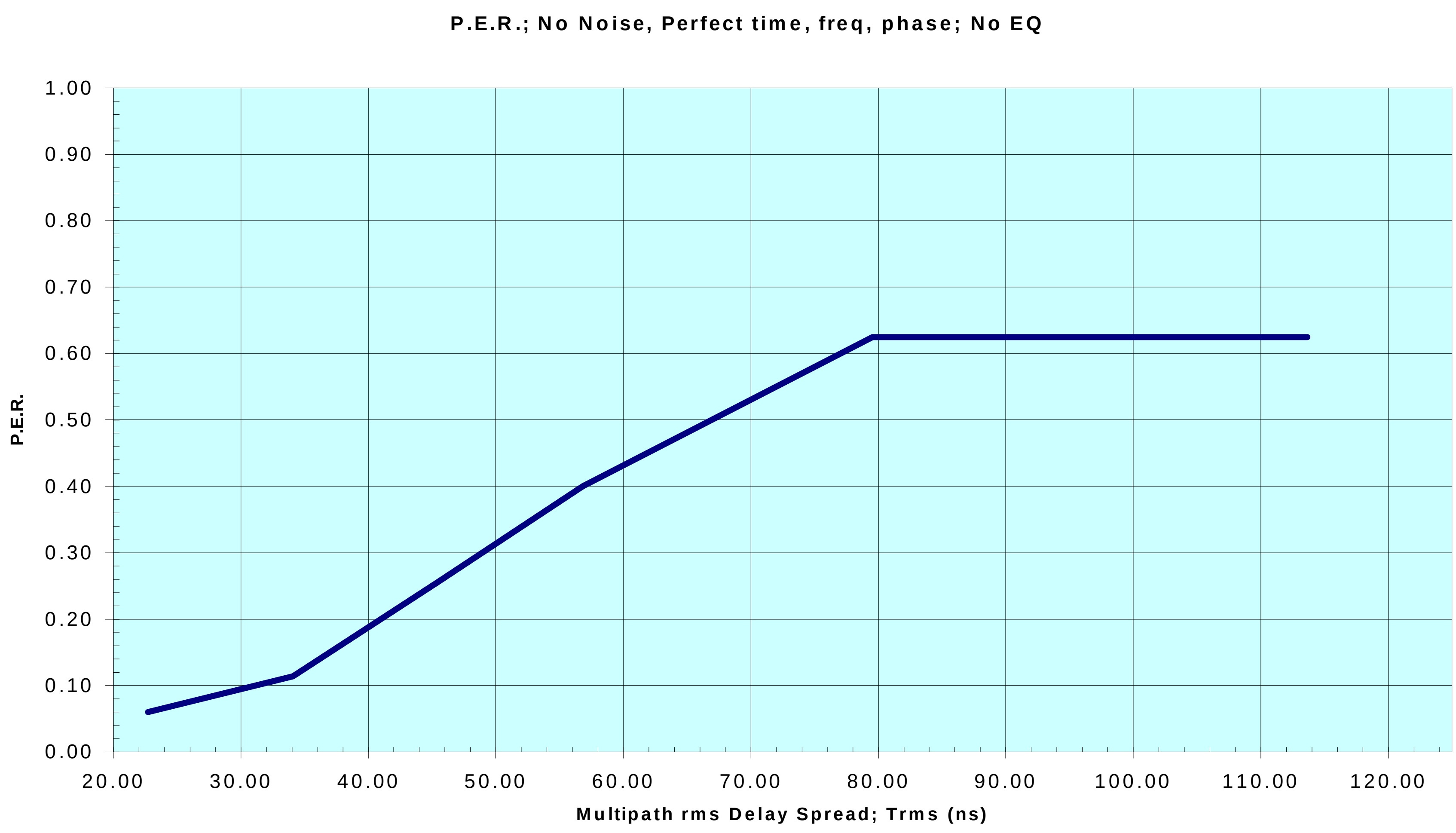


Figure 1 Graph of PER vs. Multipath rms. delay spread (no noise).

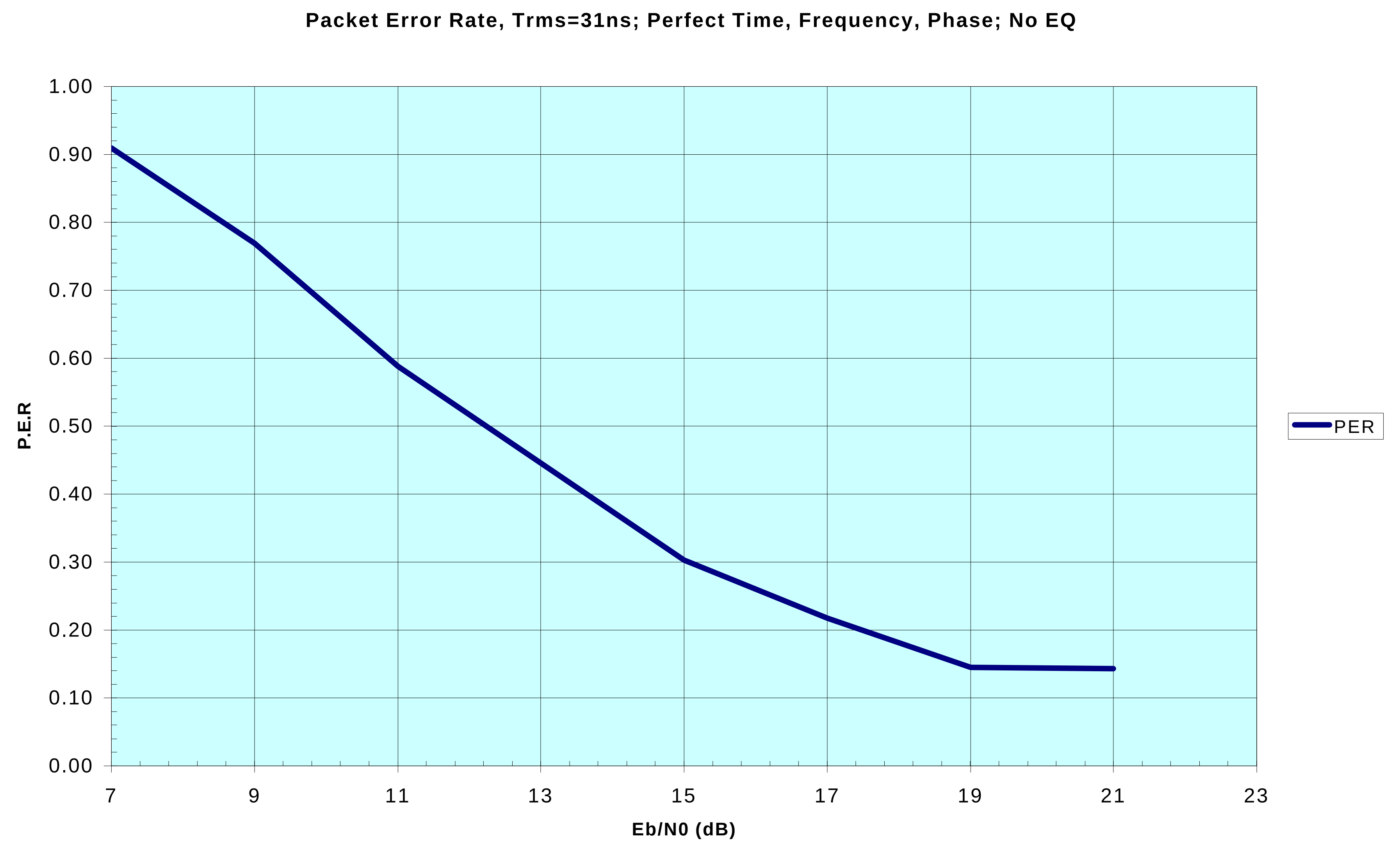


Figure 2. Graph of PER with thermal noise. (With multipath that gives PER=10% with no noise.)

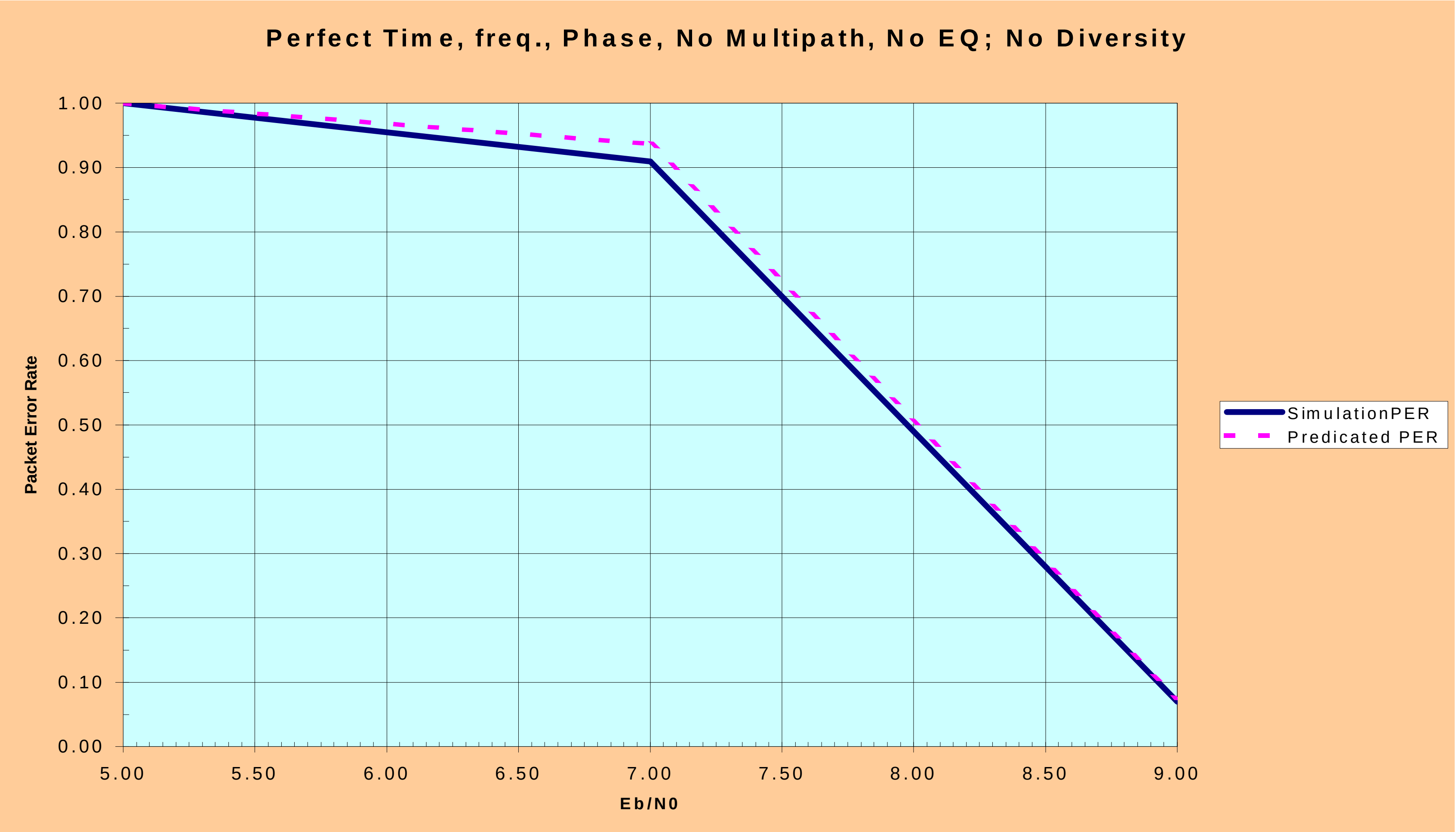
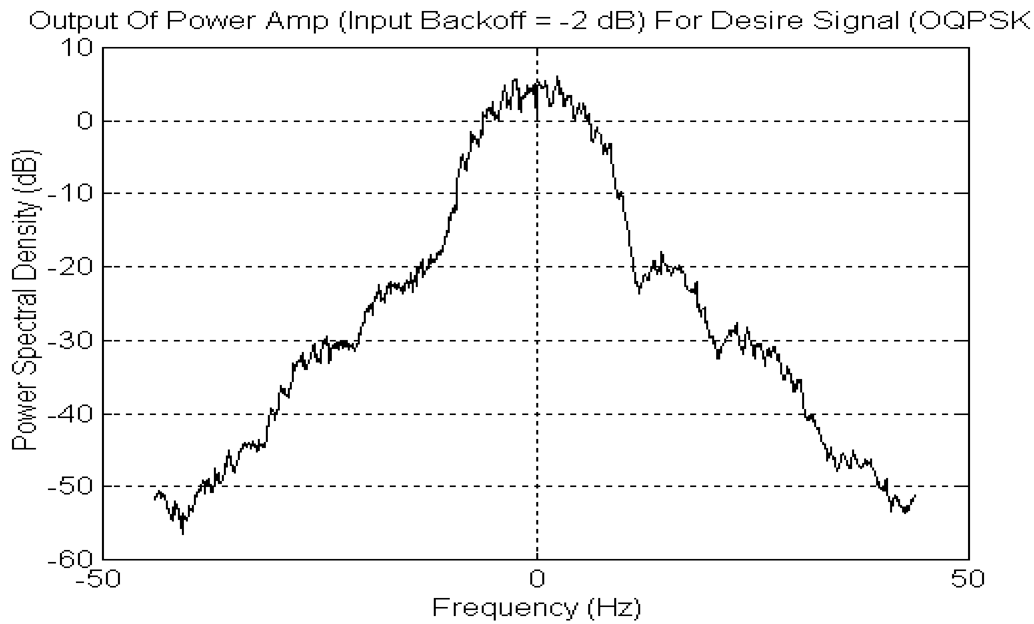


Figure 3 Graph of PER with thermal noise (no multipath.)

ıe, Freq, Phase



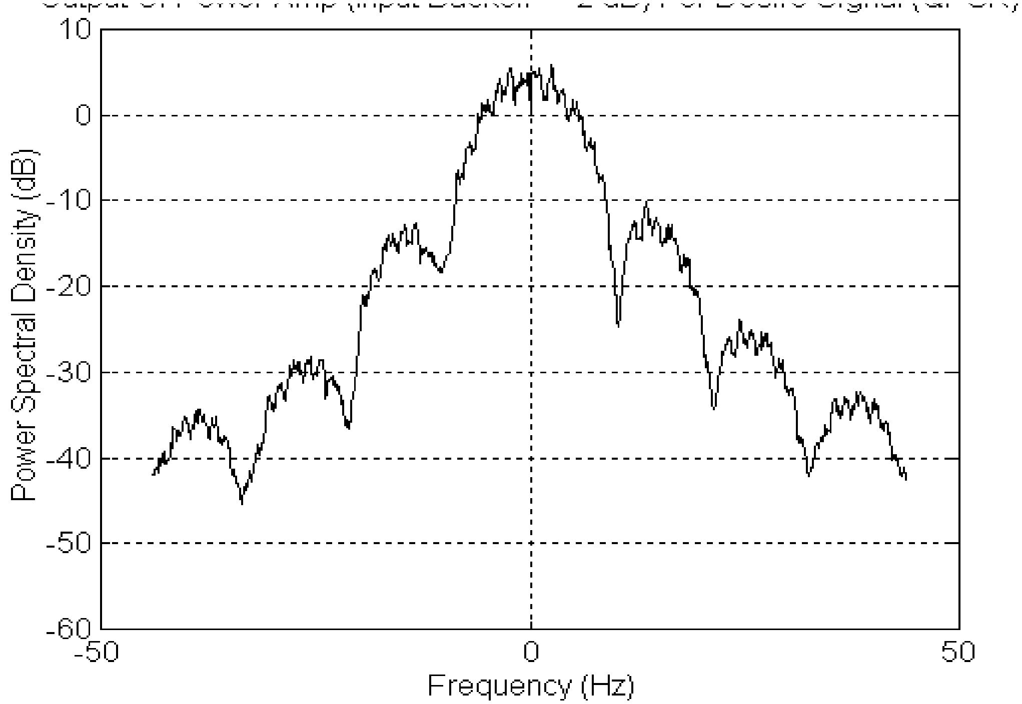


Figure 4 Graph of PER with Multipath and noise.

Figure 5. Spectrum of OQPSK Signal with output power 1 dB below MMIC Power Amplifier Saturated Power.

Figure 6. Spectrum of QPSK Signal with output power 1 dB below MMIC Power Amplifier Saturated Power.

SUMMARY: QPSK VS. OQPSK:

OQPSK allows better power efficiency.

For the same transmitted power, 3 dB difference in backoff translates to ≈2x difference in Power Amp dc power consumption. This translates into an estimated 20% less power consumption for the entire card, if OQPSK is used instead of QPSK.

OQPSK is compatible with present DS header.

Lower data rate header can be backed off by switching in an attenuator before the Power Amplifier. Switch the attenuator out for High Data Rate or use "Offset BPSK" at same backoff as OQPSK data. ("Offset BPSK" has ≈1.5 dB degradation with respect to BPSK.)

CONCLUSION:

OQPSK offers the same link performance benefits as QPSK but requires less dc power consumption. OQPSK is a superior approach.