

# SIMULATED MULTIPATH RESULTS OF PROPOSED TG3 OFDM SYSTEM

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This presentation is for improvement of phy proposals for 802.16.3 TG3

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**SIMULATED MULTIPATH RESULTS OF PROPOSED TG3 OFDM SYSTEM  
IEEE TG3 CONTRIBUTION 48**

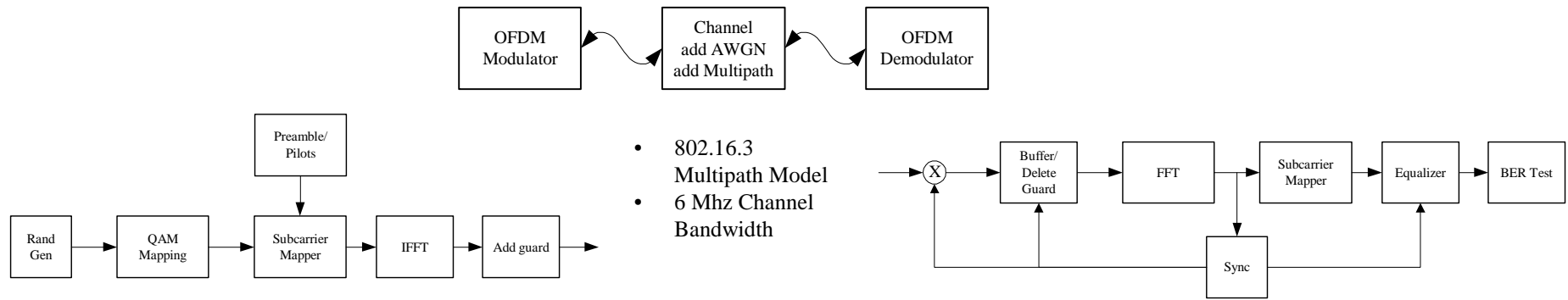
March 01

Bob Ward

## SUMMARY

- Objective
  - Preliminary evaluations of proposed TG3 OFDM system in multipath in support of the standardization process
  - Demonstrate the utility of flexible OFDM structures to various multipath scenarios
- System Description
  - OFDM modulation with various FFTsizes: 64, 256, 512, 1024, 2048
  - AWGN + Multipath channel
  - Self synchronizing burst demodulator
- Results
  - Preliminary at this point
    - Not all of modes have been tested against the SUI models yet
  - Conservative in some respects: “Pull in” of tracking mechanisms not yet employed
    - For example: Noisiness of initial channel estimate is reduced by LMS algorithm during tracking
  - Multipath delay of the SUI models are easily mitigated via the proposed OFDM system

## SIMULATION CONFIGURATION



### • OFDM SYMBOL STRUCTURE

- Preamble
  - Modified short/long structure with similar properties as 802.11a
  - Number of short symbols can be increased to more than 10 for tests
  - Two long symbols, equal in length to selected FFT size
- Data Symbols
  - FFT size: 64, 256, 512, 1024, 2048, 4096
  - Guard ratios: 1/64, 1/32, 1/16, 1/8, 1/4, of active FFT part
  - QAM modes: BPSK, QPSK, 16QAM, 64QAM,
  - Data Subcarrier Mask
    - $-M, -M+1, \dots, -1, 0, 1, \dots, +M$
    - Generally the ratio of active subcarriers to FFT size is held constant
      - $2M/\text{FFTsize} = 52/64$  for convenient comparisons
- Packet Lengths
  - Max simulated: 6500 bytes

## SYNCHRONIZATION: ACQUISITION ONLY

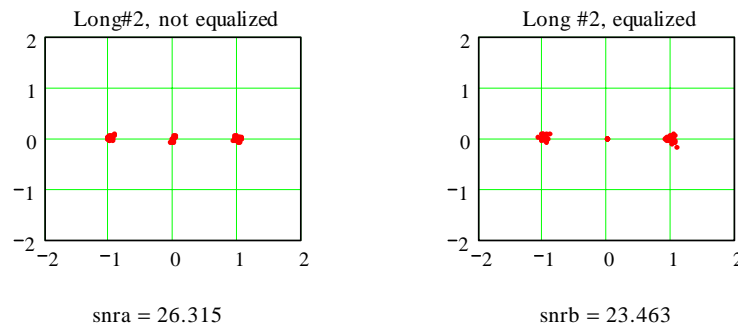
- **Burst by burst**
  - To be conservative, force acquisition in the multipath channel without benefit of prior synchronization knowledge based on framing and pilot mechanisms of proposed system
  - Thus, should expect improved performance when prior knowledge is used
- **Short Symbols used for coarse synchronization**
  - FFT timing
  - AGC
  - Frequency offset
    - Not estimated. Easy methods exist, based on experience from 802.11a
  - Long symbol identification
- **Long Symbols used for channel estimation only**
  - As shown in 802.11a system, can also refine coarse synchronization estimates
  - However, not performed here to make results more conservative
- **Tracking not utilized at this point**
  - “Pull in” of tracking mechanisms not yet employed. Thus improved performance can be expected
    - For example: Noisiness of initial channel estimate is reduced by LMS algorithm during tracking

## TEST PREAMBLE STRUCTURE

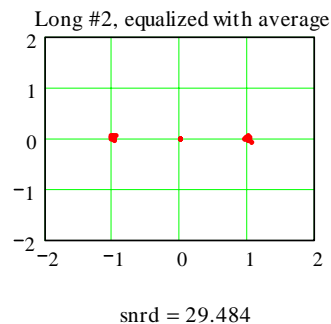
- Short/Long configuration similar to 802.11a
- Short Structure
  - 802.11a - Ten short symbols: 0.8  $\mu$ sec
  - 802.16.3 Test model
    - Periodic every 16 samples, same as for base 64 point FFT 802.11a system for all FFT sizes
    - Spacing scales upward for larger FFT sizes
    - Programmable number of short symbols; eg more than ten short symbols selectable
    - QPSK 1+j
- Long Structure
  - 802.11a – 2 ½ Basic Long symbol of 64 points
  - 802.16.3 Test Model
    - 2 ½ times FFTsize of particular mode
    - BPSK: +/- 1
    - Masked to same length as data

## EQUALIZER INITIALIZATION

- It is a noisy estimate based on two long symbols
- Example of noise effect,
  - $E_s N_{odb} = 25$
  - Long symbol #1 used to initialize equalizer. Then it is applied to #2. A comparison of the SNR on #2 before and after equalization demonstrates the potential noise degradation.



- Simple averaging across the two long symbols reduces noise effect as shown with the averaged equalizer applied to Long #2



## MULTIPATH OVERVIEW

- From the reference model

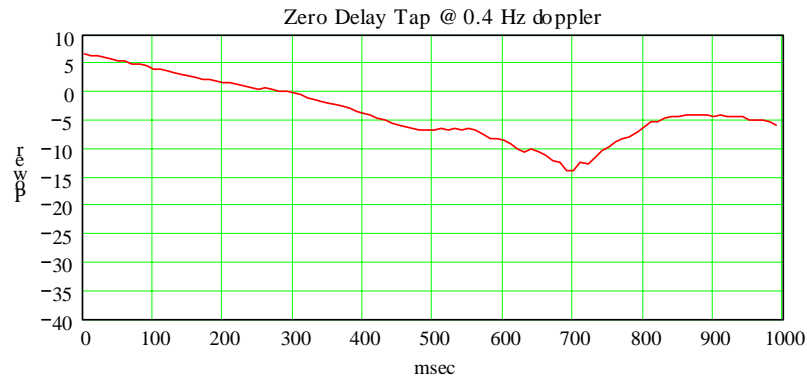
SUI – 1 Channel				
	Tap 1	Tap 2	Tap 3	Units
Delay	0	0.4	0.8	$\mu$ s
Power (omni ant.)	0	-15	-20	dB
K Factor (omni ant.)	4	0	0	
Power (30° ant.)	0	-21	-32	dB
K Factor (30° ant.)	16	0	0	
Doppler	0.4	0.4	0.4	Hz

- Multipath generation
  - Each of the three taps driven by low pass filtered complex AWGN process, with specified power relationships
  - Kfactor specifies presence of fixed tap value relative to noise processes
  - New tap values per burst; held constant for burst



## DOPPLER EFFECT IS VERY SLOW

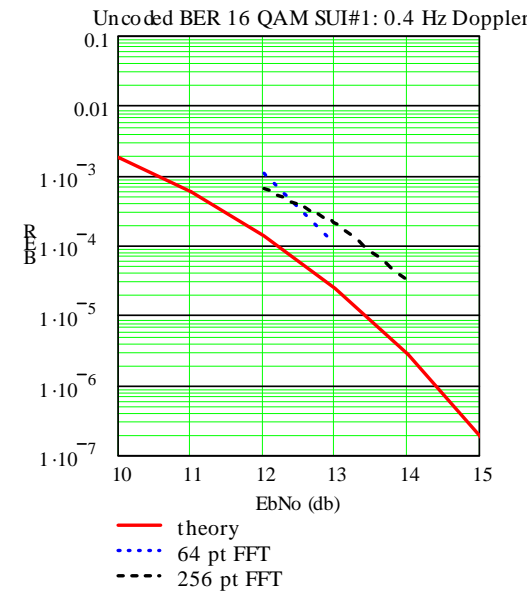
- SUI #6, omni, one instance



- Fades
  - Causes received SNR to drop below BER operating points needed for desired output coded error rates
  - Must be countered by a diversity scheme, such as included in proposed system, or other.
- BER simulations
  - Thus failed acquisition due to fade occur. Less frequent with Kfactor > 0

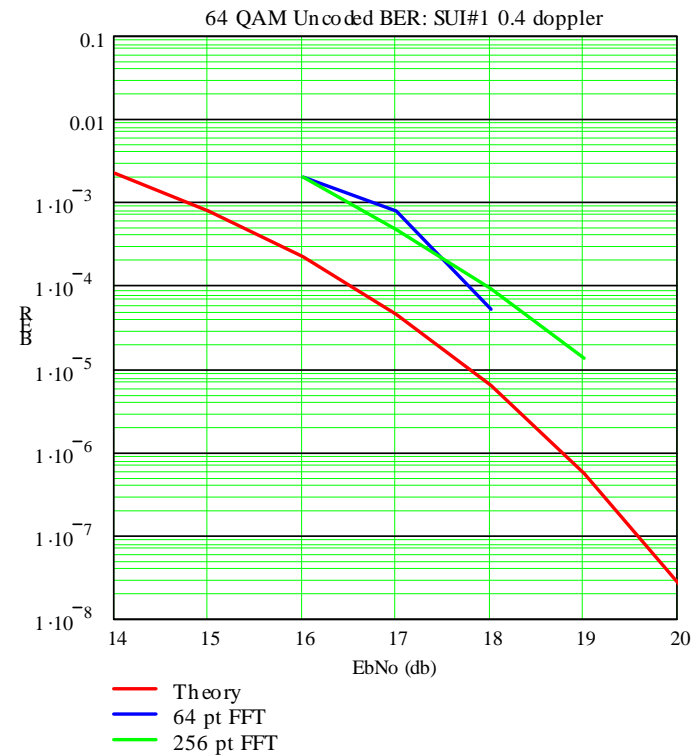
## 16 QAM UNCODED BER EXAMPLE SUI#1

- 6 Mhz channel
- SUI#1
  - -15 db @ 0.4 and -20 db @ 0.8  $\mu$ sec
  - 0.4 hz doppler
  - K factor = 4
- OFDM characteristics
  - 64 pt FFT
    - $\frac{1}{4}$  guard
    - 52 subcarriers
  - 256 pt FFT
    - $\frac{1}{4}$  guard
    - 208 subcarriers
  - Preamble based synchronization
- Observations
  - Multipath within guard of both FFTs so similar performance
  - Uncoded operating point below  $10^{-3}$  is achievable. Thus, coded performance will be excellent
  - Both 64 and 256 point FFT have same data throughput



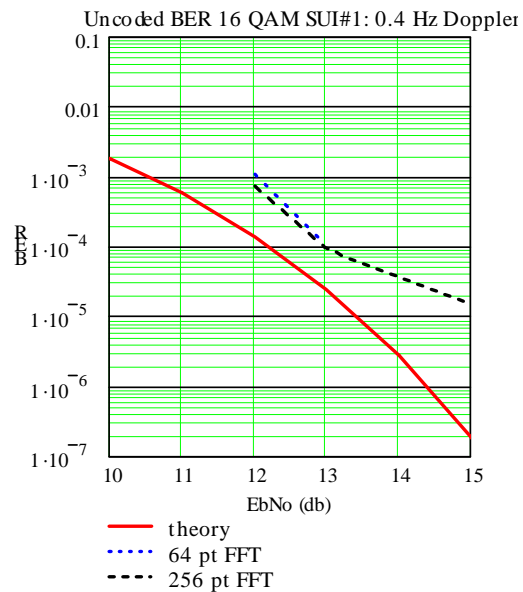
## 64 QAM UNCODED BER EXAMPLE SUI#1

- Same as 16 QAM
- Observations
  - Very Similar performance to 16 QAM



## 16 QAM EXAMPLE REVISITED BUT WITH REDUCED GUARD

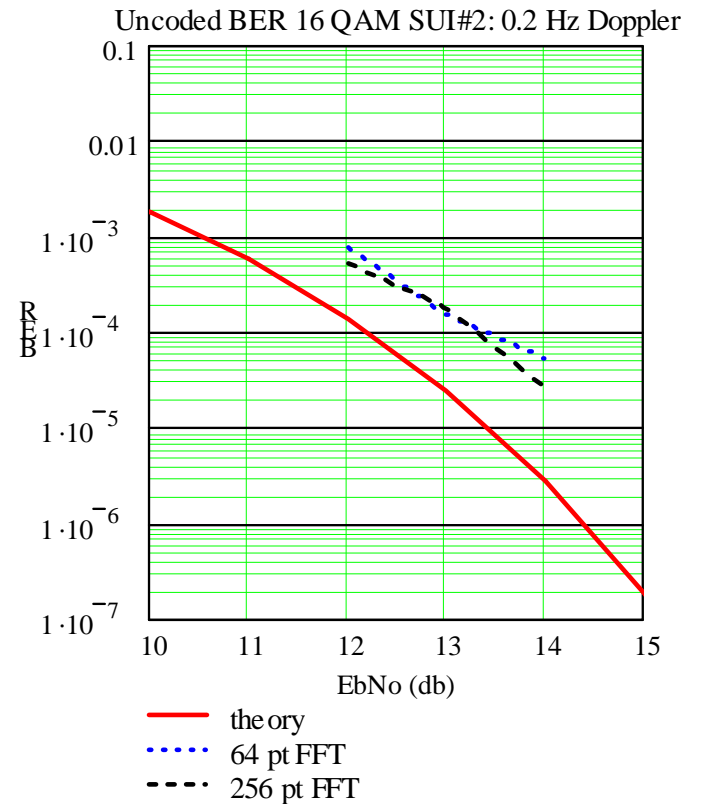
- For the 256 point FFT case, 0.8  $\mu$ sec max delay permits reducing guard from  $\frac{1}{4}$  to  $\frac{1}{8}$ 
  - Slightly better efficiency with reduced guard
  - Similar performance (close again to 64 point FFT curve), but indications that performance may not be as good as  $\frac{1}{4}$  guard for lower BERs
  - Again could expect FEC to reduce the error rate



## SUI#2 16 QAM

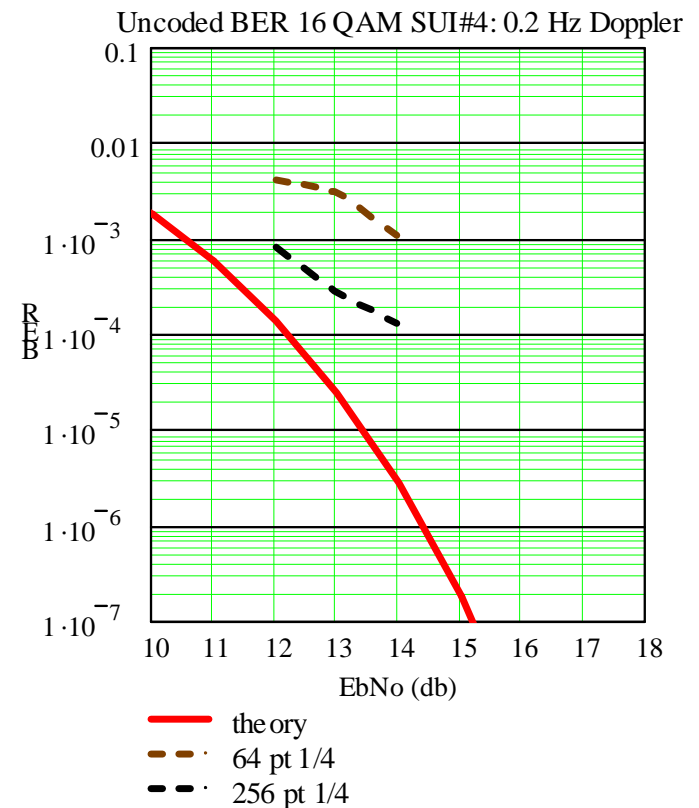
- 6 Mhz channel
- SUI#2
  - -12 db @ 0.5 and -15 db @ 1  $\mu$ sec
  - 0.2 hz doppler
  - K factor = 2
- OFDM characteristics
  - 64 pt FFT
    - 1/8 guard
    - 52 subcarriers
  - 256 pt FFT
    - 1/8 guard
    - 208 subcarriers
  - Preamble based synchronization
- Observations
  - Multipath of similar length, but reduced guard of both FFTs
  - Uncoded operating point below  $10^{-3}$  is achievable. Thus, coded performance will be excellent
  - Both 64 and 256 point FFT have same data throughput

On the 64 point FFT,  
two failed  
acquisitions due to  
deep fade not  
included



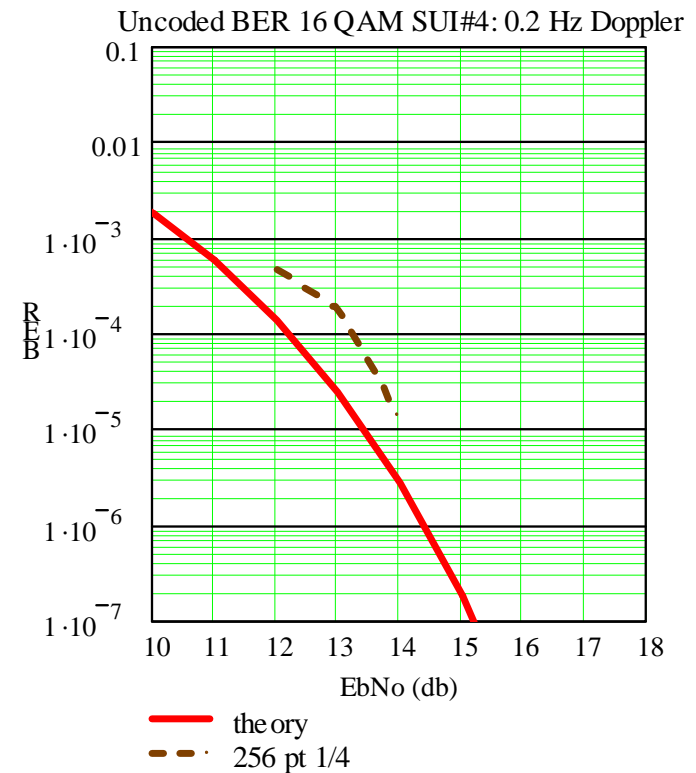
## SUI#4 16 QAM OMNI Antenna

- 6 Mhz channel
- SUI#4 - Hot
  - -4 db @ 2 and -8 db @ 4  $\mu$ sec
  - 0.2 hz doppler
  - K factor = 0
- OFDM characteristics
  - 64 pt FFT
    - 1/4 guard (on the order of 2.6  $\mu$ sec)
    - 52 subcarriers
  - 256 pt FFT
    - 1/4 guard (on the order of 9.3  $\mu$ sec)
    - 208 subcarriers
  - Preamble based synchronization
- Observations
  - 64 point FFT suffering
  - 256 point FFT about 2 db off
  - Uncoded operating point below  $10^{-3}$  is achievable.  
Thus, coded performance will be excellent



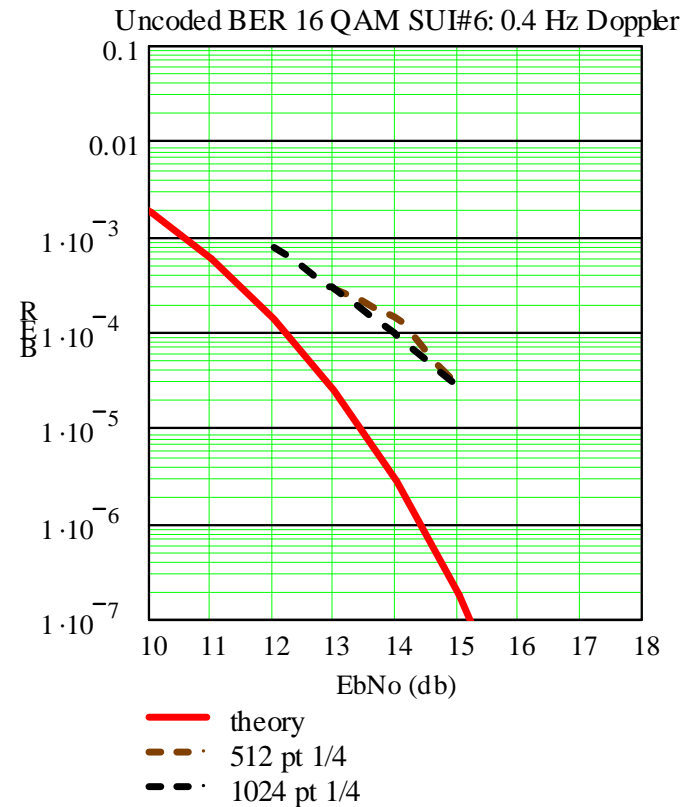
## SUI#4 16 QAM 30 degree Antenna

- 6 Mhz channel
- SUI#4 - Cooler
  - -10 db @ 2 and -20 db @ 4  $\mu$ sec
  - 0.4 hz doppler
  - K factor = 0
- OFDM characteristics
  - 256 pt FFT
    - 1/4 guard (on the order of 9.3  $\mu$ sec)
    - 208 subcarriers
- Observations
  - 256 point FFT performance is better as expected
  - Uncoded operating point below  $10^{-3}$  is achievable. Thus, coded performance will be excellent



## SUI #6: 16 QAM OMNI

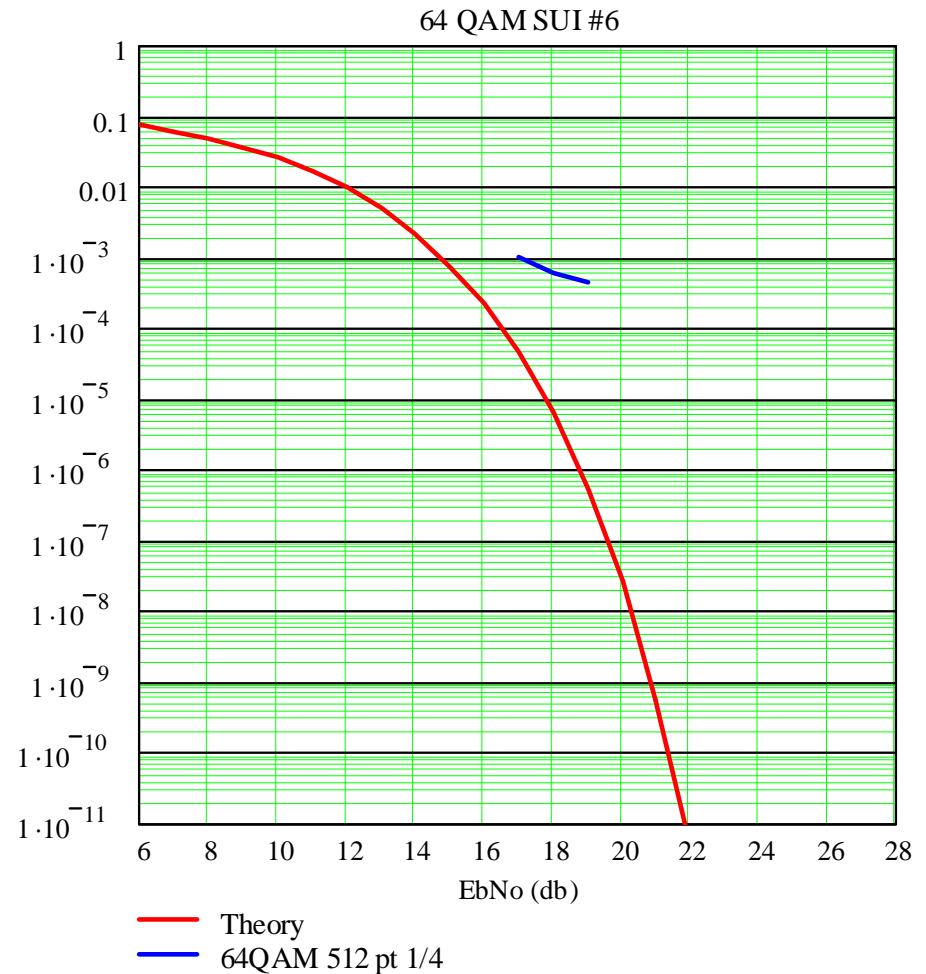
- 6 Mhz channel
- SUI#6
  - -10 db @ 10 and -14 db @ 20  $\mu$ sec
  - 0.4 hz doppler
  - K factor = 0
- OFDM characteristics
  - 512 pt FFT
    - 1/4 guard (on the order of 18.6  $\mu$ sec)
    - 416 subcarriers
  - 1024 pt FFT
    - 1/4 guard (on the order of 37.3  $\mu$ sec)
    - 832 subcarriers
  - Preamble based synchronization
- Observations
  - Note 512 can mitigate effectively beyond its guard length
  - Uncoded operating point below  $10^{-3}$  is achievable. Thus, coded performance will be excellent





## SUI #6: 64 QAM OMNI

- 6 Mhz channel
- SUI#6
  - -10 db @ 10 and -14 db @ 20  $\mu$ sec
  - 0.4 hz doppler
  - K factor = 0
- OFDM characteristics
  - 512 pt FFT
    - 1/4 guard (on the order of 18.6  $\mu$ sec)
    - 416 subcarriers
- Observations
  - Uncoded operating point below  $10^{-3}$  is achievable. Thus, coded performance will be excellent



## CONCLUSIONS & NEXT STEPS

- Conclusions
  - OFDM flexible structure vs multipath scenarios was demonstrated as a good approach
- Next Steps
  - Other modes to be included
  - More detailed models as they develop. For example
    - Framing concepts and preamble design as they relate to synchronization
    - Diversity method
      - Considered critical, for  $K = 0$  cases
    - FEC