OFDM Channel Modeling for WiMAX

April 27, 2007

David Doria

Goals:

- To develop a simplified model of a Rayleigh fading channel
- Apply this model to an OFDM system
- Implement the above in network simulation software (NS2)

What is OFDM?

- We can use one radio to transmit in an FDM system
- Orthogonality properties allow for more closely packed frequency symbols

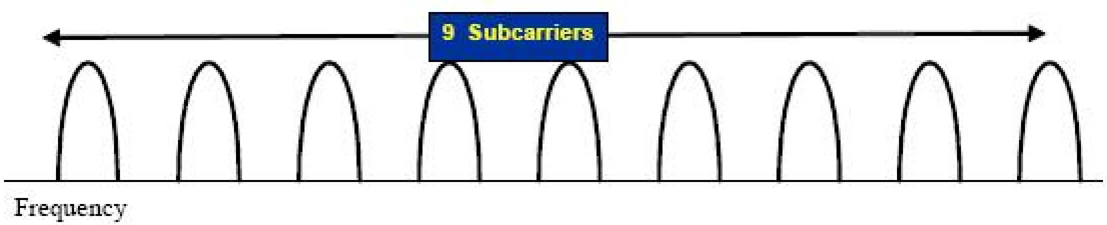
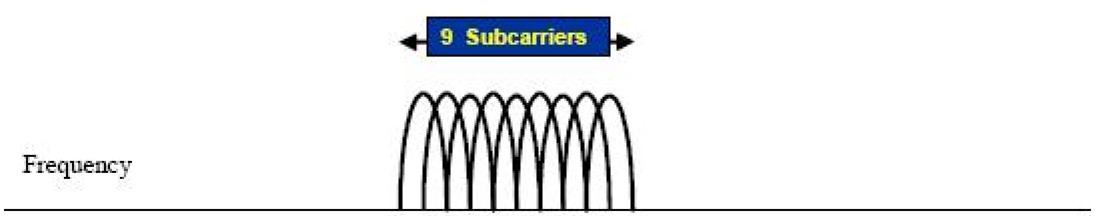
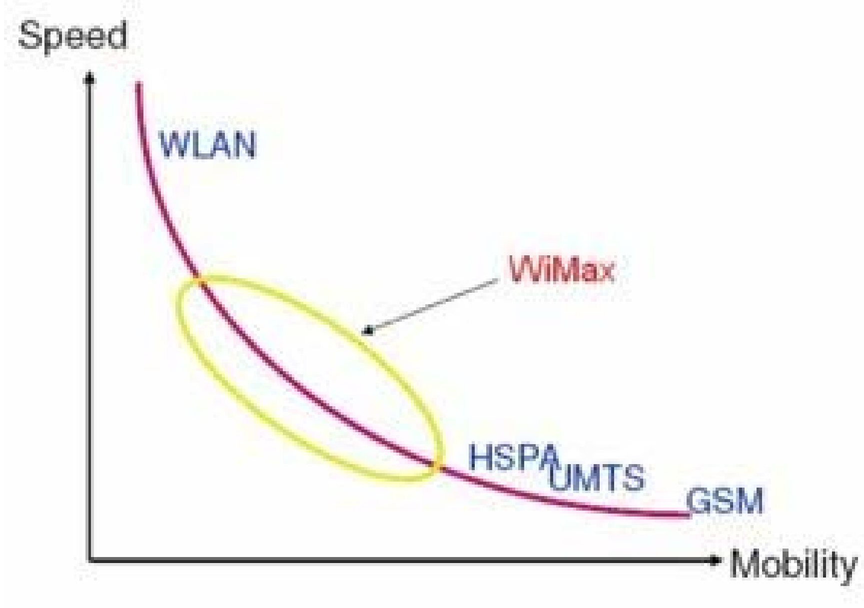


Figure 1: FDM with Nine Sub-carriers Using Filters



What is WiMAX?

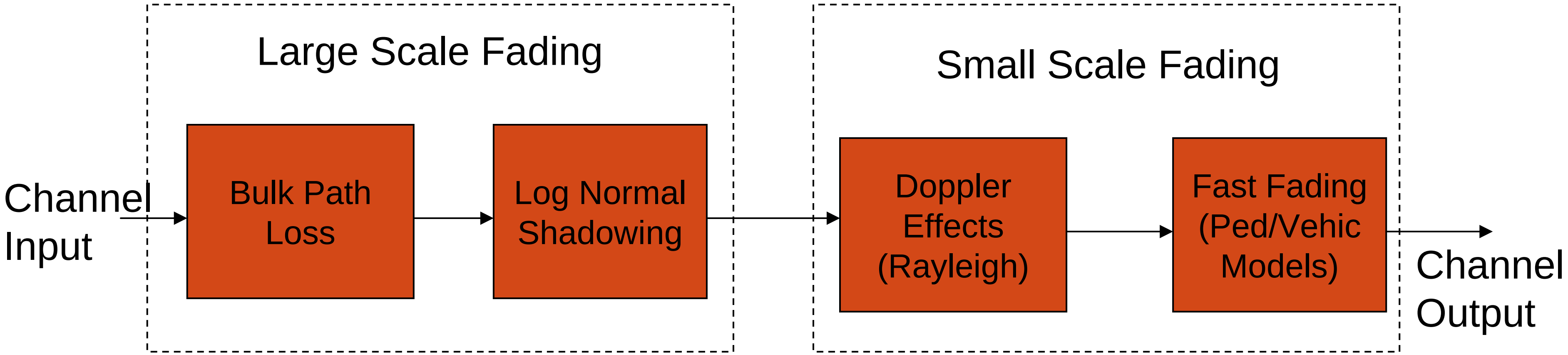
- IEEE 802.16d/e
- Speed and Mobility: best of both worlds
- Combines many new ideas into one standard (MIMO, OFDM/A, etc.)



“WiMAX aims to provide wireless data over long distances…..from point to point links to full mobile cellular type access.”

“30,000 feet” View of the Model

- Each OFDM sub-symbol is subjected to each of the following blocks



- The first 2 blocks are modeled using the Cost231 model
- Basically a black box

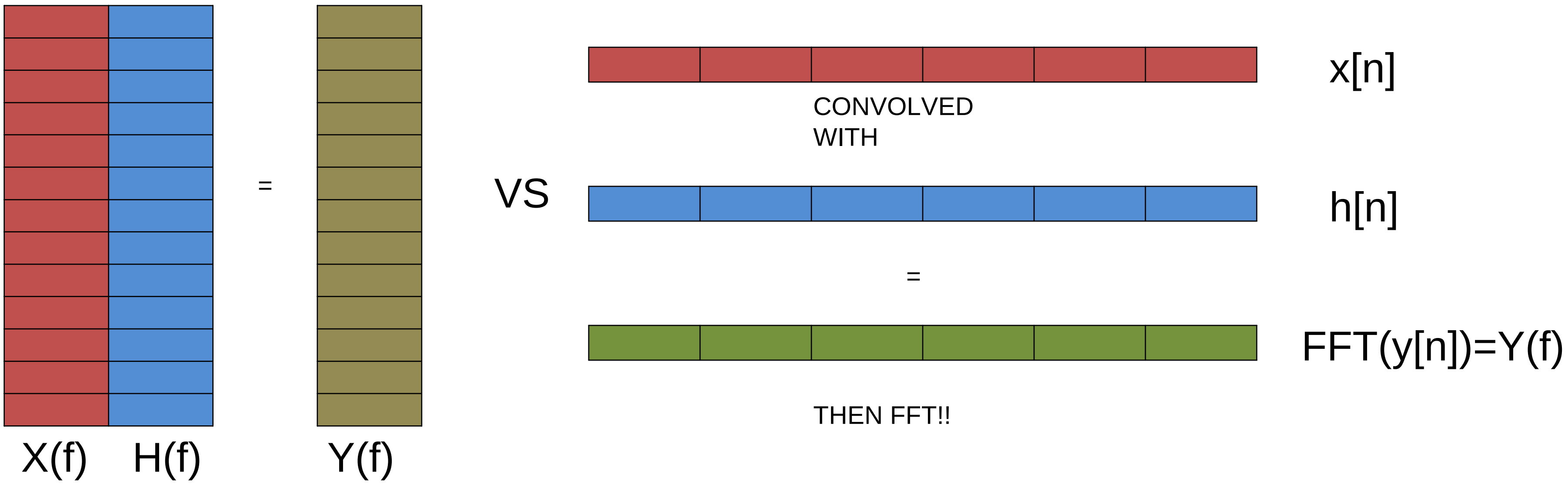
Small Scale Fading

- Takes into account multipath effects
- These effects are very complex, so statistical models are used
- To implement these models in the time domain is very computationally intensive
- Need to “skip some steps” in simulation

Problems with Time Domain Modeling

- Clearly, all communication must be done over time (aka the time domain)
- To "send" information through a channel, you must convolve x[n] with the channel impulse response h[n]
- Working in the time domain (convolution x[n]*h[n]) requires MANY more multiplication and addition operations than working in the frequency domain (multiplication X(f)H(f))
- This is too computationally intensive to be implemented in a simulation

Working in the Frequency Domain



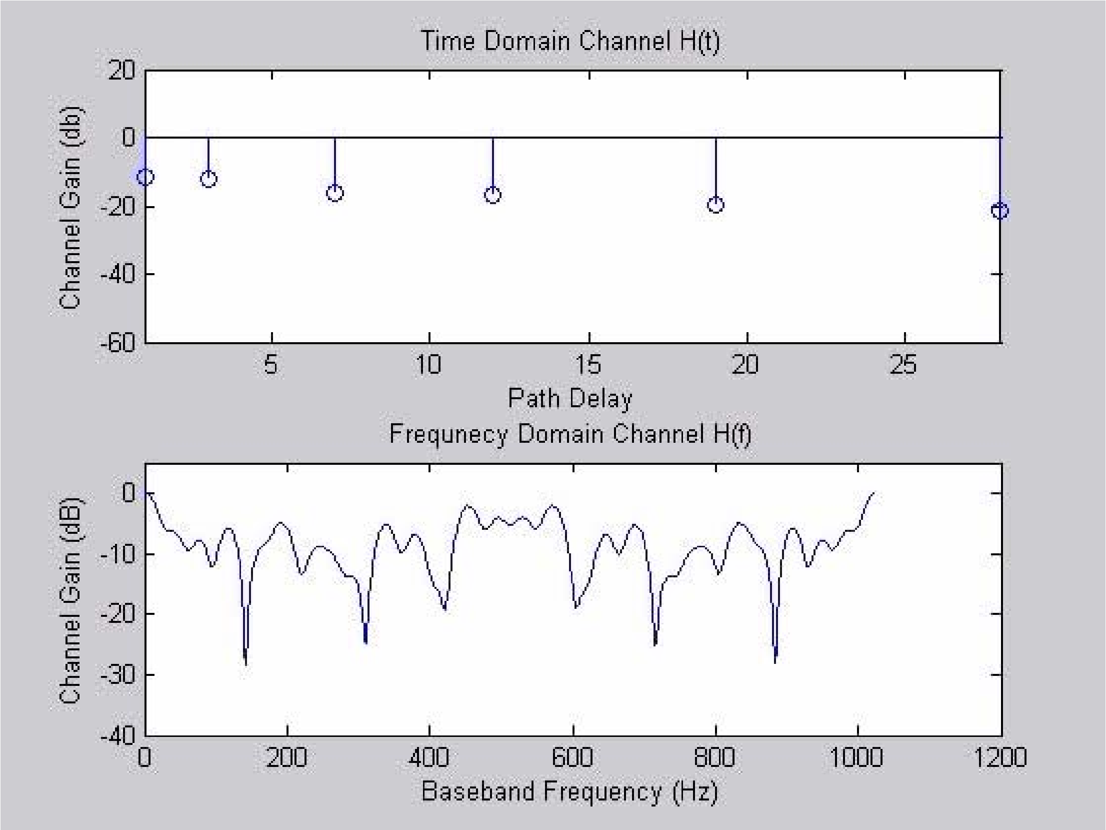
- OFDM symbols are created in the frequency domain
- Multiplication in the frequency domain is the equivalent operation to convolution in the time domain
- MUCH less computationally intensive

What we expect to see…

- The FFT of an impulse is a complex sinusoid
- Since the PDP is a sum of shifted impulses, we expect to see the sum of sinusoids (looking at abs(H(f)))
- The destructive interference of these sinusoids is what causes the channel to fade

Frequency Response

- To obtain H(f), we simply take the FFT of the PDP!

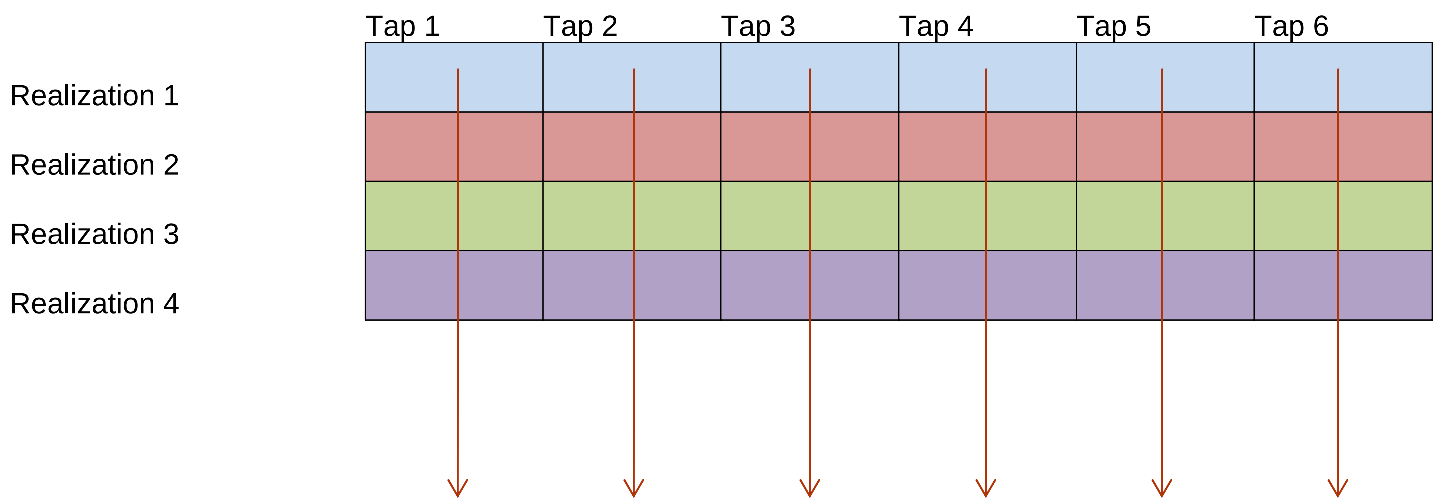


Modeling Channel Time Correlation

- The channel coherence time is assumed to be 5ms
- Therefore, the mobile should see a different but related channel every 5ms
- To model this correlation, we weight the taps of the PDP by time correlated Rayleigh numbers, then take the FFT to obtain H(f)

Where is the Correlation?

- Looking at each row of a matrix as the 6 taps weights of the channel, the correlation is down the columns!!



How To Obtain the Correlation?

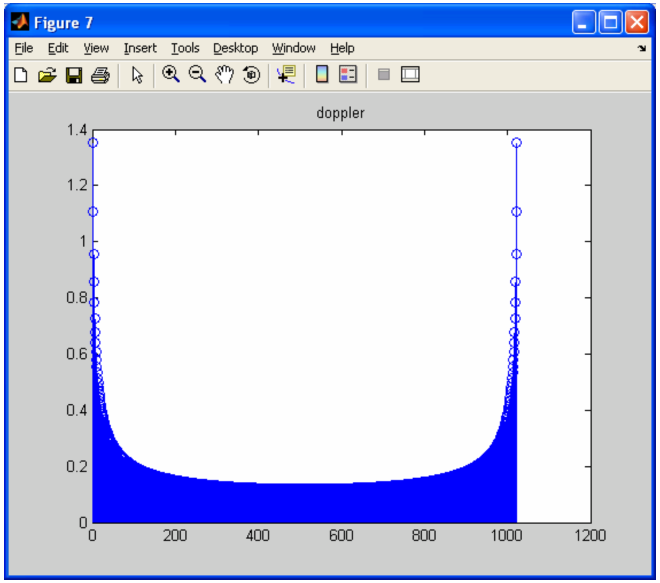
- The following process is performed for EACH COLUMN

1. Generate N IID Complex Normal Random Variables (N is the number of channel realizations you wish to obtain)
2. Generate Doppler Spectrum (Jakes Model) (also length N)
3. Multiply (1) and (2)
4. Take the IFFT to obtain a time domain sequence

OFDM Channel Model

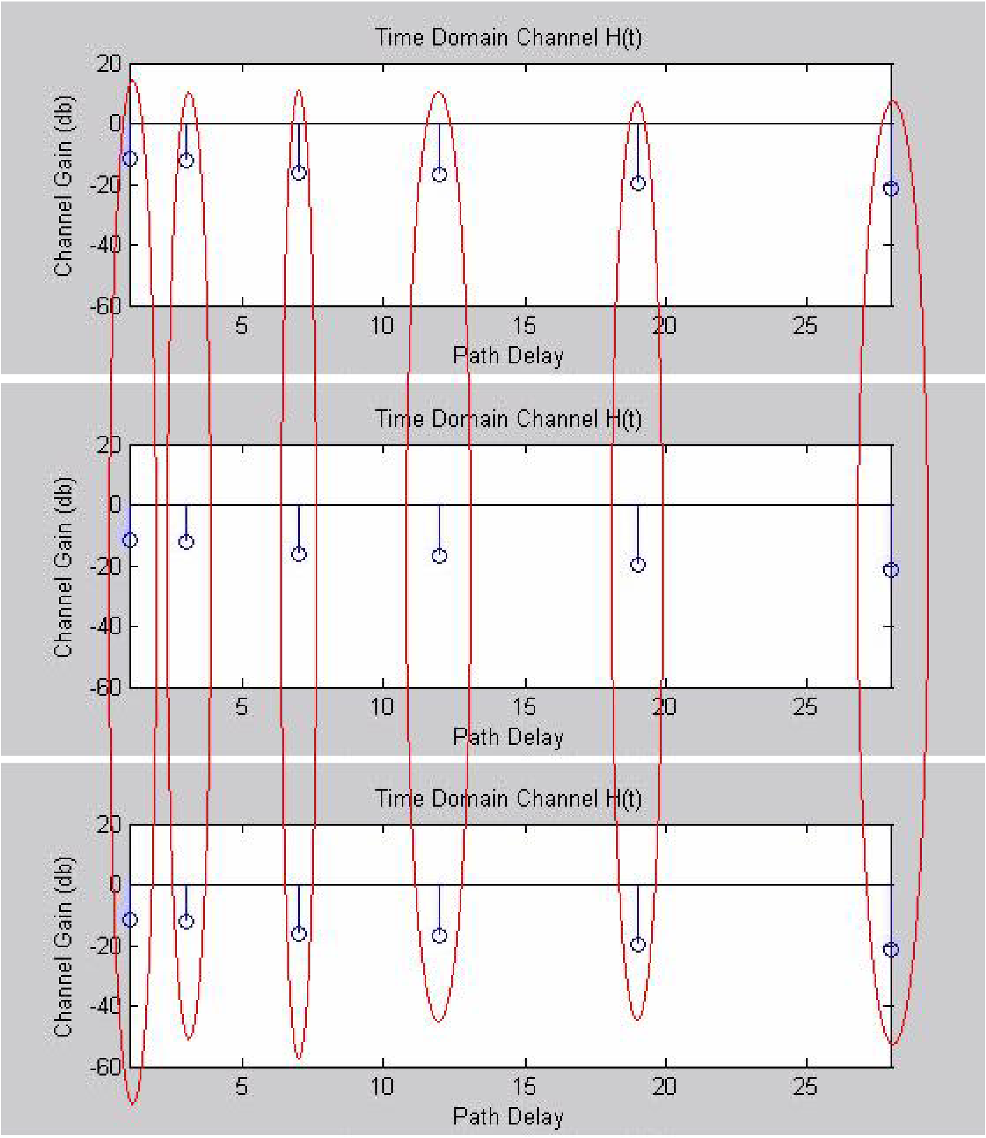
- The correlation was created with Jakes spectrum

$$D = \frac{1.5}{\pi * f_m * \sqrt{1 - \left(\frac{f - f_c}{f_m}\right)^2}}$$



Applying the Time Correlated Rayleigh Numbers

- The process in the previous slide is performed 6 times.
- Each of these 6 sets of time correlated numbers are used to weight the SAME tap in successive channel realizations (Indicated in red)
- Three successive channels are shown to the right



Getting the Frequency Domain Channel

- Scale the initial PDP with a row from the
- Take the 1024 point FFT to get the frequency domain response.

Table A.2.6.3: ITU Channel Model for Vehicular Test Environment

Tap	Channel A	
	Relative delay (ns)	Average power (dB)
1	0	0.0
2	310	–1.0
3	710	–9.0
4	1 090	–10.0
5	1 730	–15.0
6	2 510	–20.0

Implementation in NS2

- Outside of NS, generate a file of a sufficient number of channel realizations
- Create an interface to read the frequency domain channel gains from the appropriate file into an array, prior to the simulation starts.
- Simply (not THAT simply!!) multiply (Y(f)X(f))

The Problem

- Since NS2 is a packet level simulator, there is no data!! Don't have X(f)!!
- Now what do we do?
- We are only looking for the received power of a packet, so we can assume each slot in X(f) to be P/M where P is the transmit power of the OFDM symbol and M is the number of subcarriers used in the current symbol.

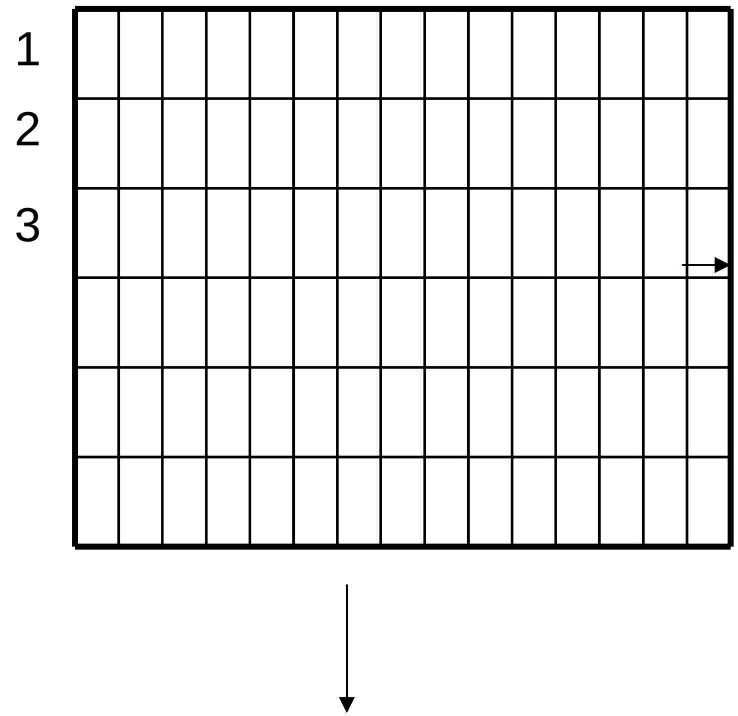
Simulating Multiple, Uncorrelated Channels (Cont.)

- The file is organized as a 2-dimensional matrix with Y-axis as independent channel realizations and X-axis the frequency domain channel response.

- Every coherence time, each user is assigned a random number from 1 to NumChannelRealizations

- A maximum of NumChannelRealizations users can be simulated simultaneously with uncorrelated channels.

Channel File Structure



THANK YOU!

QUESTIONS???