EFFICIENT STRATEGIES FOR REPRESENTING AND EVALUATING THE EFFECT OF PROPAGATION IMPAIRMENTS ON THE PERFORMANCE OF WIRELESS COMMUNICATIONS SYSTEMS

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- Response surface models
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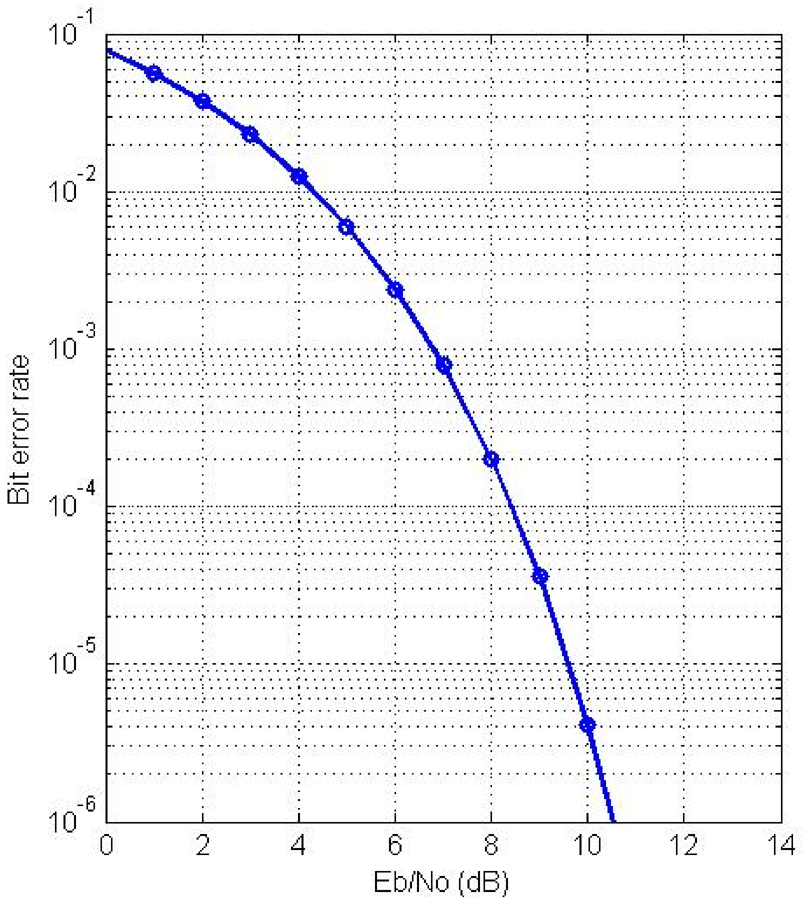
Motivation

- Current needs
  - Simple cases:

    The link-level performance of wireless communications system can be adequately characterized by determining the manner in which BER degrades as the SNR at the receiver input decreases.
  - Higher frequencies and more challenging environments:

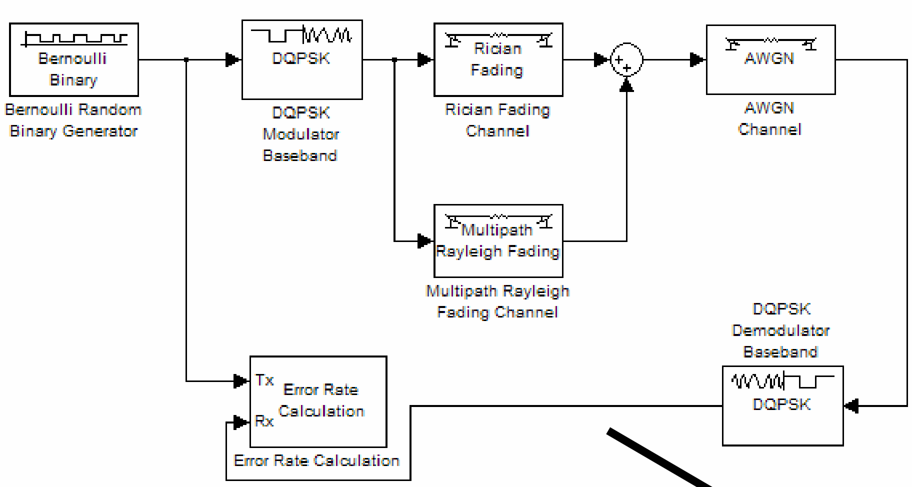
    it is necessary to account for the effects of a time-varying and/or frequency selective channel.

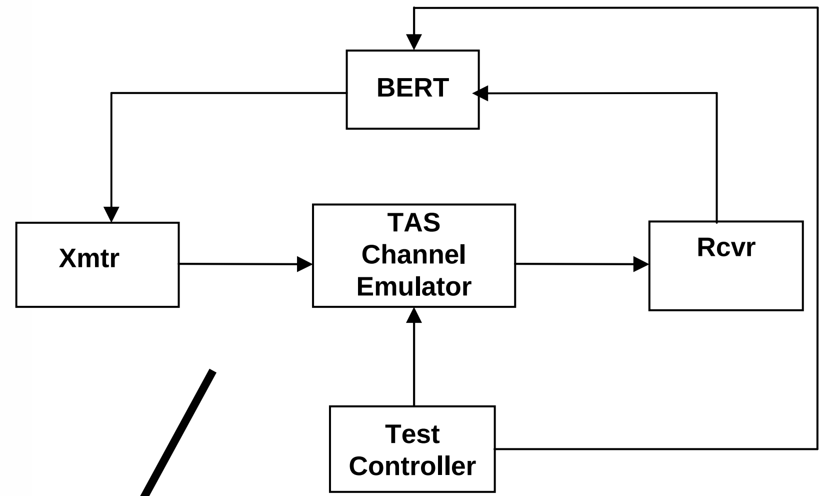


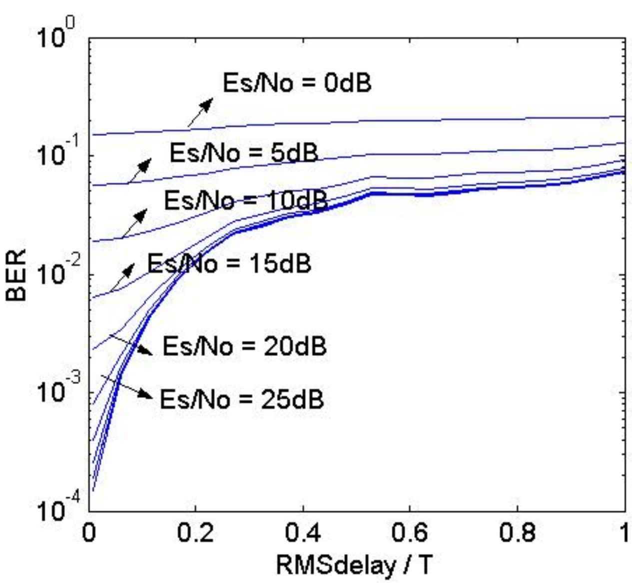
Motivation

- Current approaches
  - Standard Channel Models
    - Typical Urban (TU), Bad Urban (BU), etc.
    - FIR filters with specified tap delays, amplitudes, and time variation
  - Dynamic Environment Emulation
    - Testing using simulated drive test data
- Limitations of current approaches
  - yield results that apply only to certain specific channel conditions
  - only produce statistical summaries of link-level performance over a particular set of channel conditions
  - a more complete description of link-level performance is required for applications
    - system-level simulation
    - visualization of link-level performance across a broad range of channel conditions

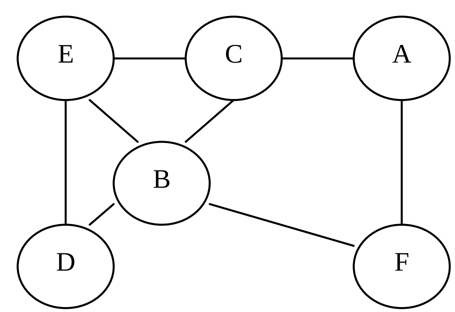
Motivation







IEEE 802.11 TgT Wireless Performance Prediction



Objective

Propose alternative methods for representing and evaluating the effect of propagation impairments on the performance of wireless communications systems that overcome limitations of current approaches

- Response Surface Models
  - To represent the system performance compactly
- Adaptive Sampling
  - To reduce the time required to generate RSMs

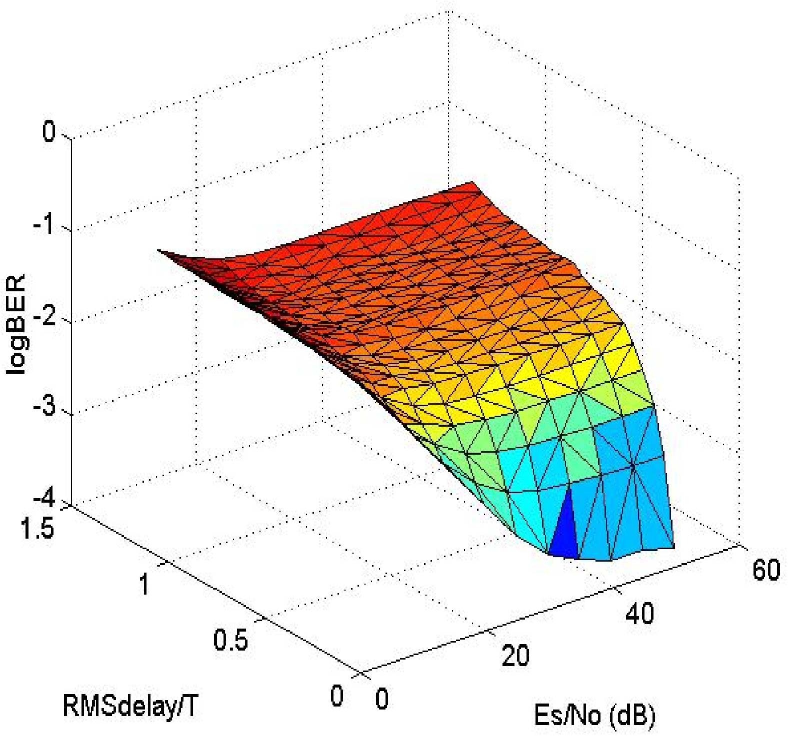
Response surface models (RSMs)

- Objective:

  Efficiently yet compactly represent the performance of wireless communications systems as a function of propagation channel parameters for the purposes of both system level simulation and visualization of system performance over a broad range of channel conditions

Response surface models (RSMs)

- Approaches to visualizing the performance of wireless communication systems in the presence of propagation impairments
  - two dimensional representations (BER vs. one or two channel parameters)
  - Three dimensional representations (BER vs. two channel parameters)

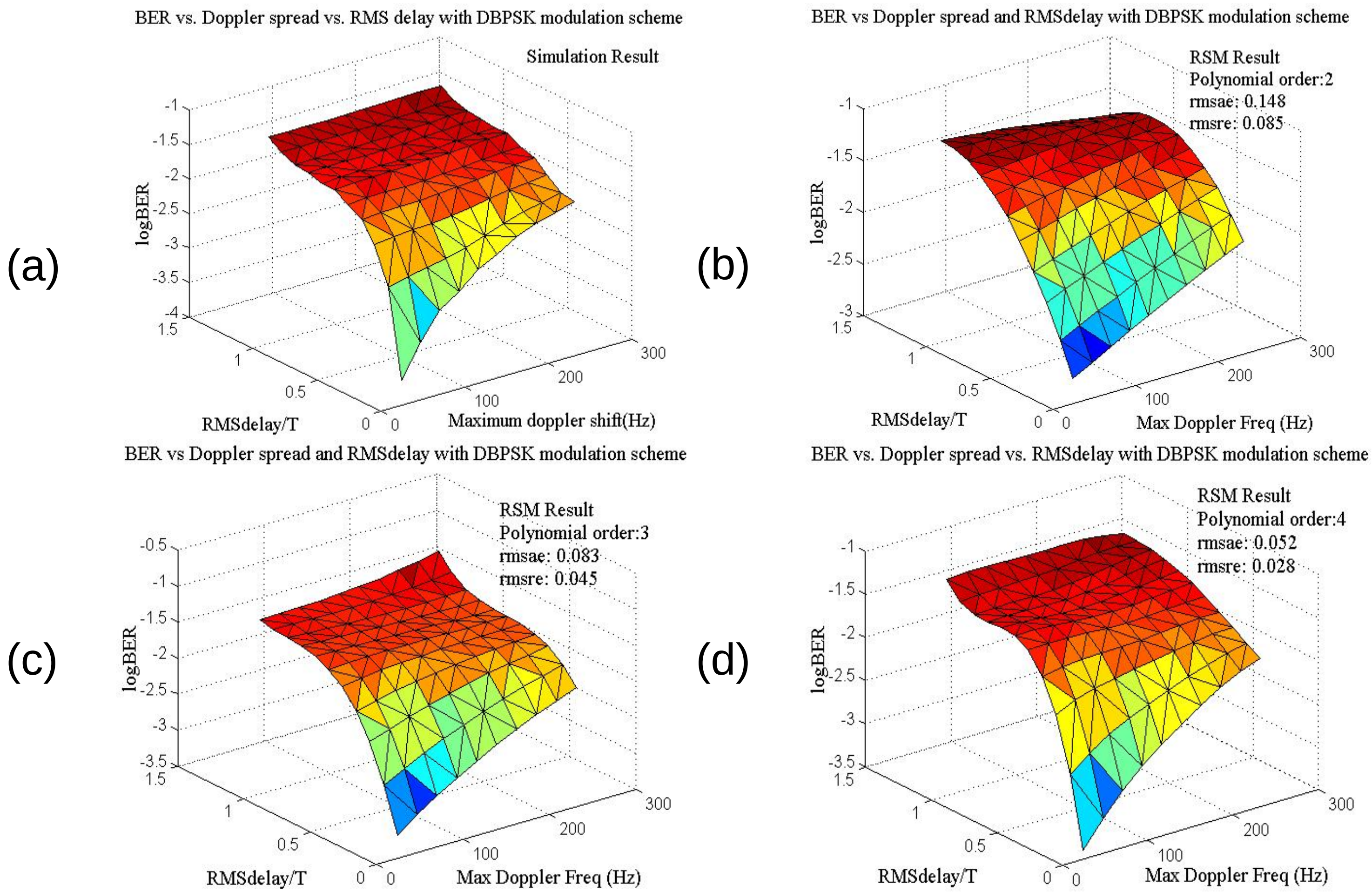


Response surface models (RSMs)

- Simplification of the performance surfaces
  - Concept of response surface models
    - RSMs in Design of Experiment (DOE)
    - RSMs used to simplify the performance surfaces of wireless communication systems
  - Generation of response surface models
    - Models
      - quadratic polynomial model
      - Higher-order polynomial model
    - Tools
      - Matlab function: *nlinfit*
      - Matlab function: *nlintool*
    - Verification
      - Absolute error (residue)
      - Relative error (scaled residue)

Response surface models (RSMs)

- An example of response surface models



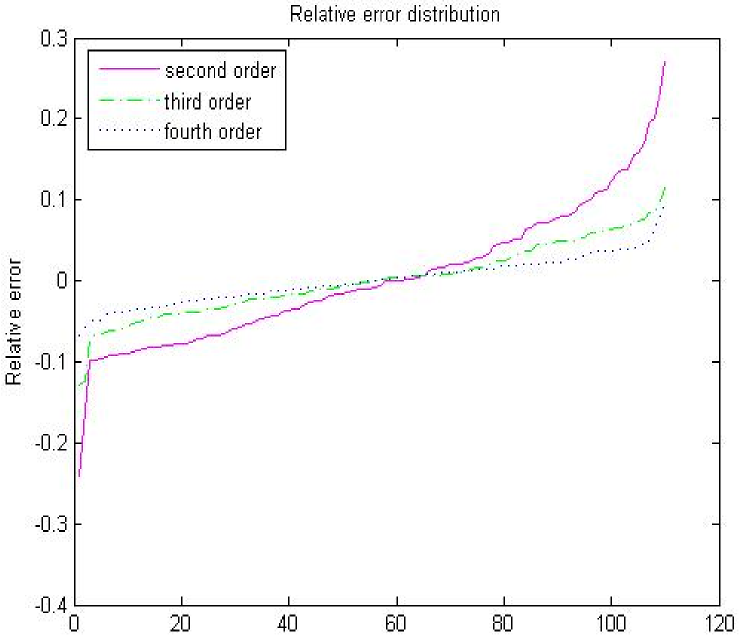
Comparison of BER surfaces (BER vs. RMS delay/T vs. Doppler spread for DBPSK modulation scheme) generated by simulation and response surface models

Response surface models (RSMs)

- An example of response surface models

Order of polynomial model	Number of model parameters	RMSE of absolute error	RMSE of relative error (%)
2	6	0.148	8.5%
3	10	0.083	4.5%
4	15	0.052	2.8%

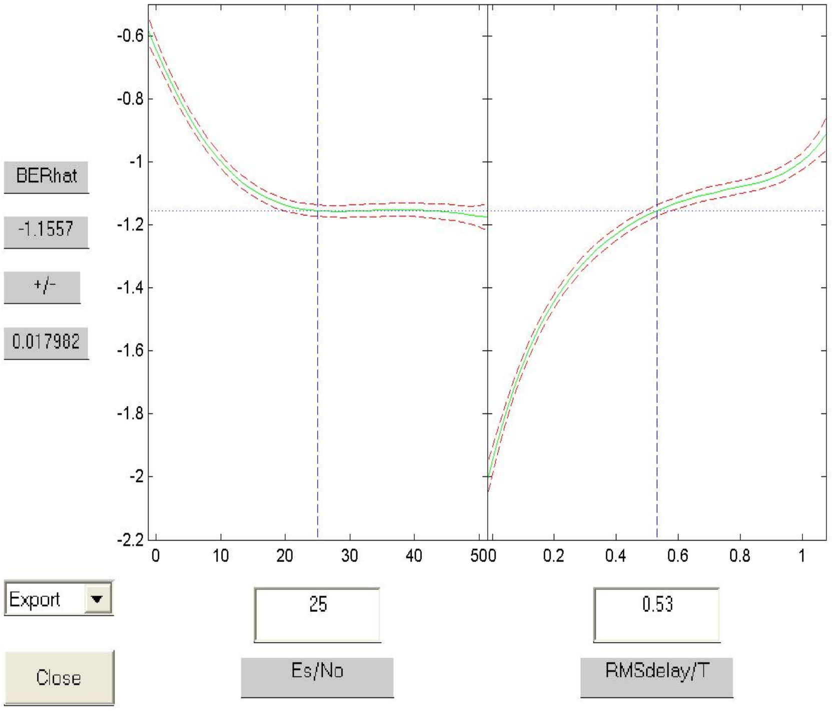
Comparison of RMSE obtained from different response surface models by fitting the surface of BER vs. RMS delay /T vs. Doppler spread with DBPSK modulation



Distribution of relative errors obtained from different polynomial models

Response surface models (RSMs)

- Applications
  - Visualization of the performance of wireless communication systems
  - System level simulation
  - Evaluation of the performance of system equipments
  - Performance comparison of different equipments



Performance of wireless communication system (BER vs. RMS delay/T vs. Es/No for MSK modulation scheme) show in *nlintool* GUI

Response surface models (RSMs)

- Conclusion
  - Correct, compact and complete representation of the performance of wireless communications system
  - Easy to be generated by Matlab functions
  - Many applications

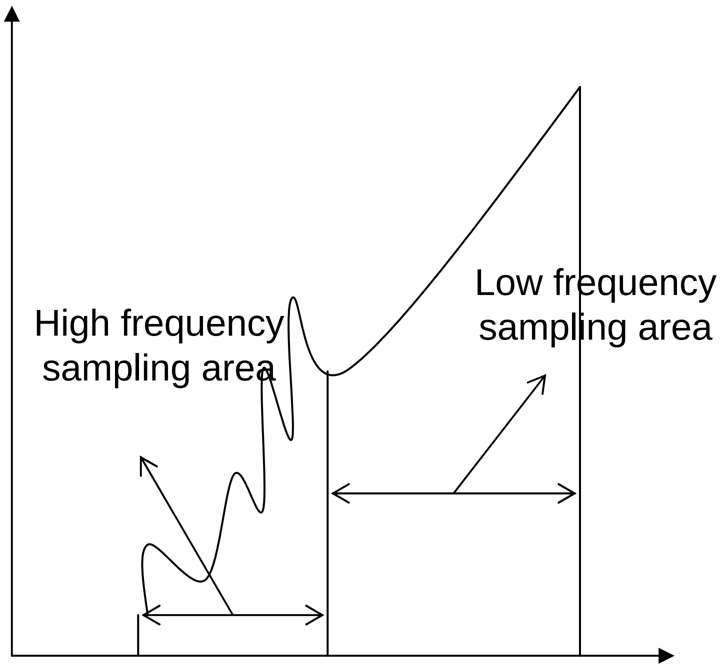
Adaptive sampling

- Objective:

  Significantly reduce the time and effort required to generate a response surface model from physical layer simulations

- Concept:

  Over a given area, fewer samples are needed with the variable sampling rate while maintaining the similar response characteristics compared with traditional fixed rate sampling



Adaptive sampling

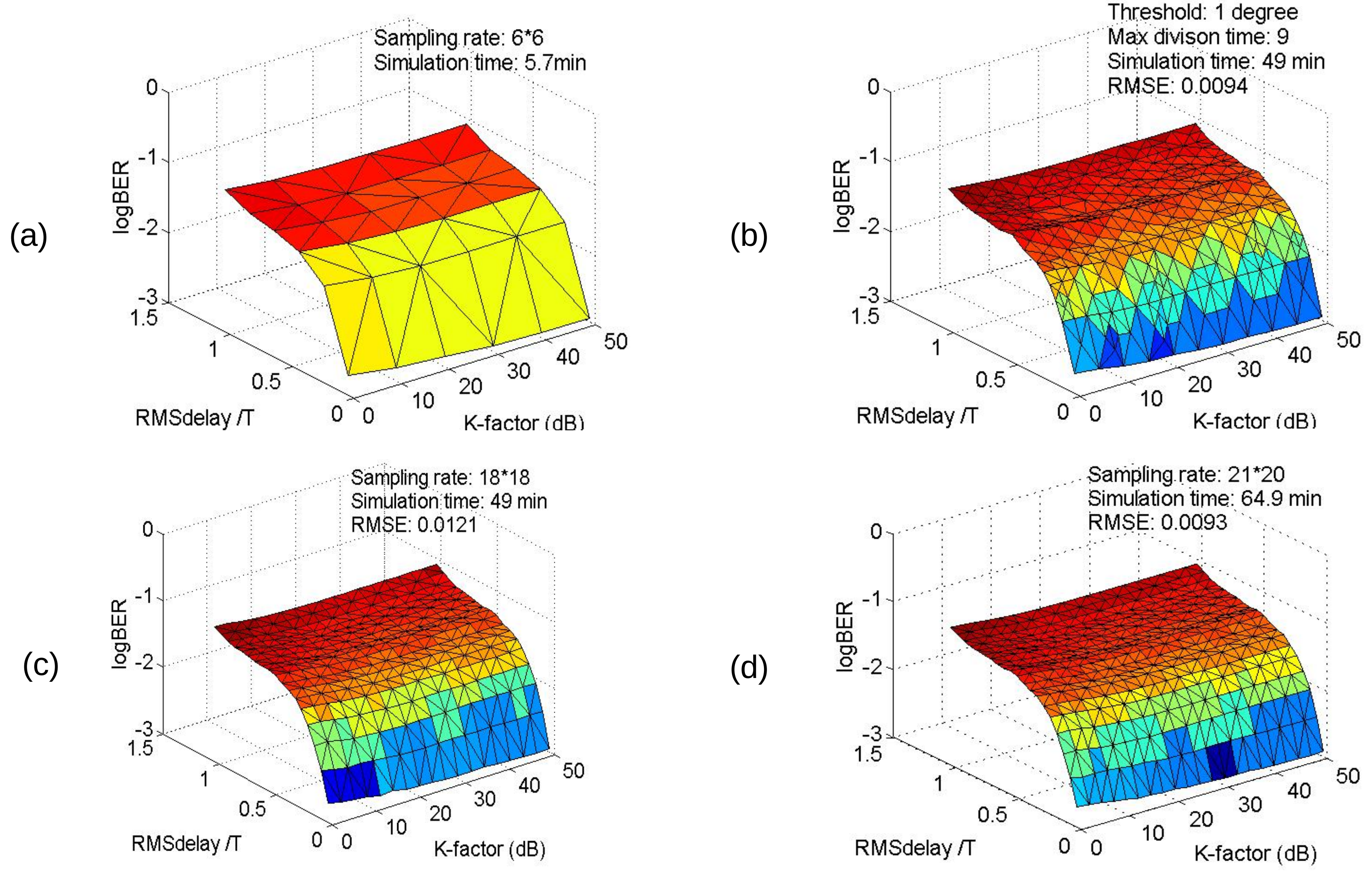
- Basic idea: two-phase sampling
  - Coarse sampling (low-rate fixed rate sampling)
    - Map the general shape of the surface into a continuous set of triangular plates (Delaunay triangulation)
  - Adaptive sampling
    - Divide each triangular plate until all the triangular plates or sub-triangular plates meet some criteria
    - Criteria (two thresholds)
      - Angle between triangular plate and sub-triangular plates
      - Maximum number of divisions

Adaptive sampling

- Method used to verify adaptive sampling algorithm
  - Three fixed rate sampling runs are needed to compare with adaptive sampling
    - The first fixed-rate sampling run spends similar simulation time with adaptive sampling
    - The second fixed-rate sampling run obtains the similar RMSE with adaptive sampling
    - The third fixed-rate sampling run is the reference to calculate RMSE which has a high sampling rate

Adaptive sampling

- An example of adaptive sampling



Comparison of adaptive and fixed rate sampling when they are implemented in the simulations to generate BER vs. K-factor vs. RMS delay/T for DBPSK modulation

Adaptive sampling

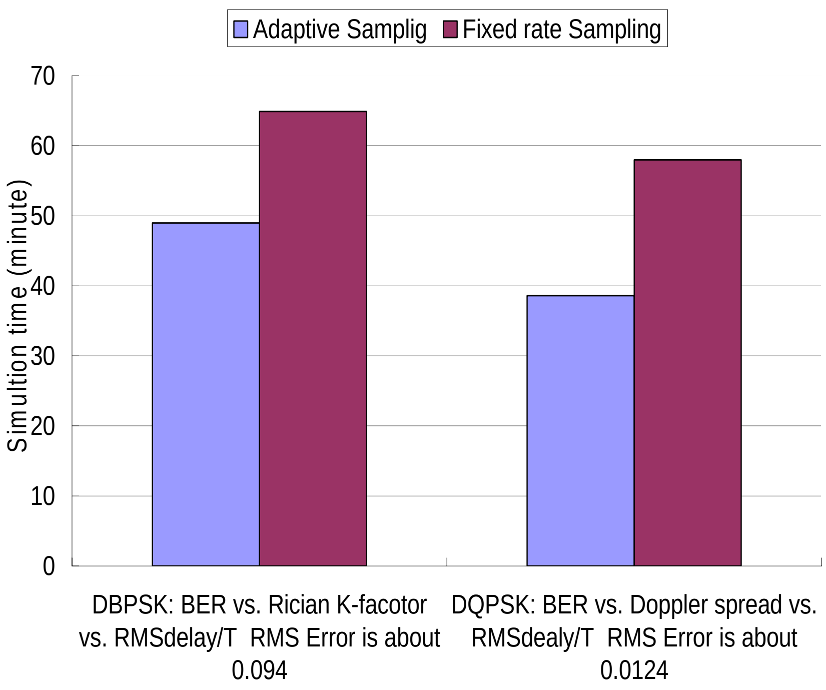
- An example of adaptive sampling

Sampling method		Total generated points	Total simulation time (minute)	RMSE compared with the third fixed-rate sampling
Coarse sampling		36	5.7	0.0581
Adaptive sampling		324	49	0.0094
Fixed-rate sampling	Rate 1	324	49	0.0121
	Rate 2	420	64.9	0.0094
	Rate 3	441	66.4	0

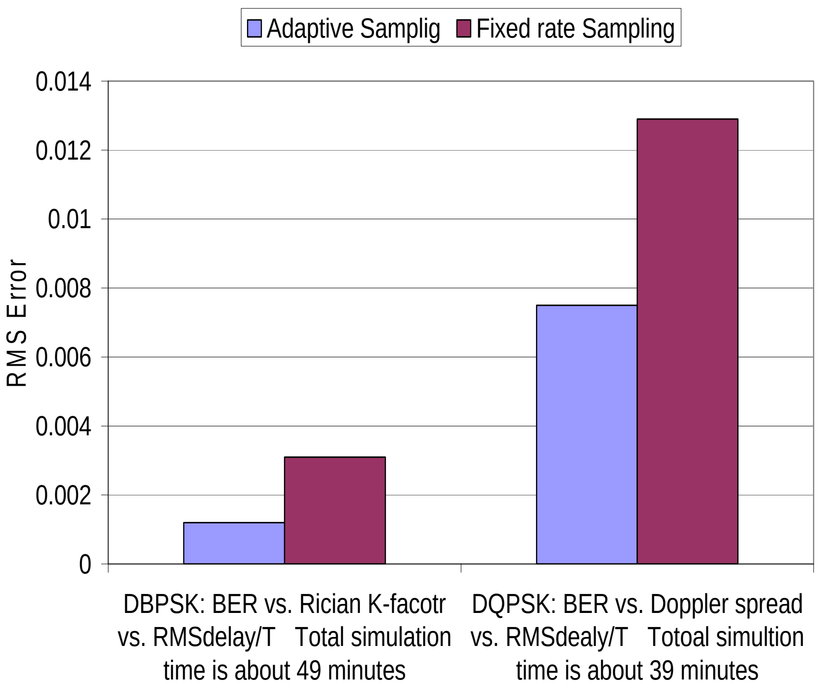
Comparison of adaptive and fixed rate sampling when they are implemented in the simulations to generate BER vs. K vs. RMS delay/T for DBPSK modulation For the fixed-rate sampling, the Rate 1 is 18*18(K*RMS delay/T), Rate 2 is 21*20 and Rate 3 is 21*21

Adaptive sampling

- An example of adaptive sampling



Simulation time comparison of adaptive and fixed rate sampling given similar RMSE

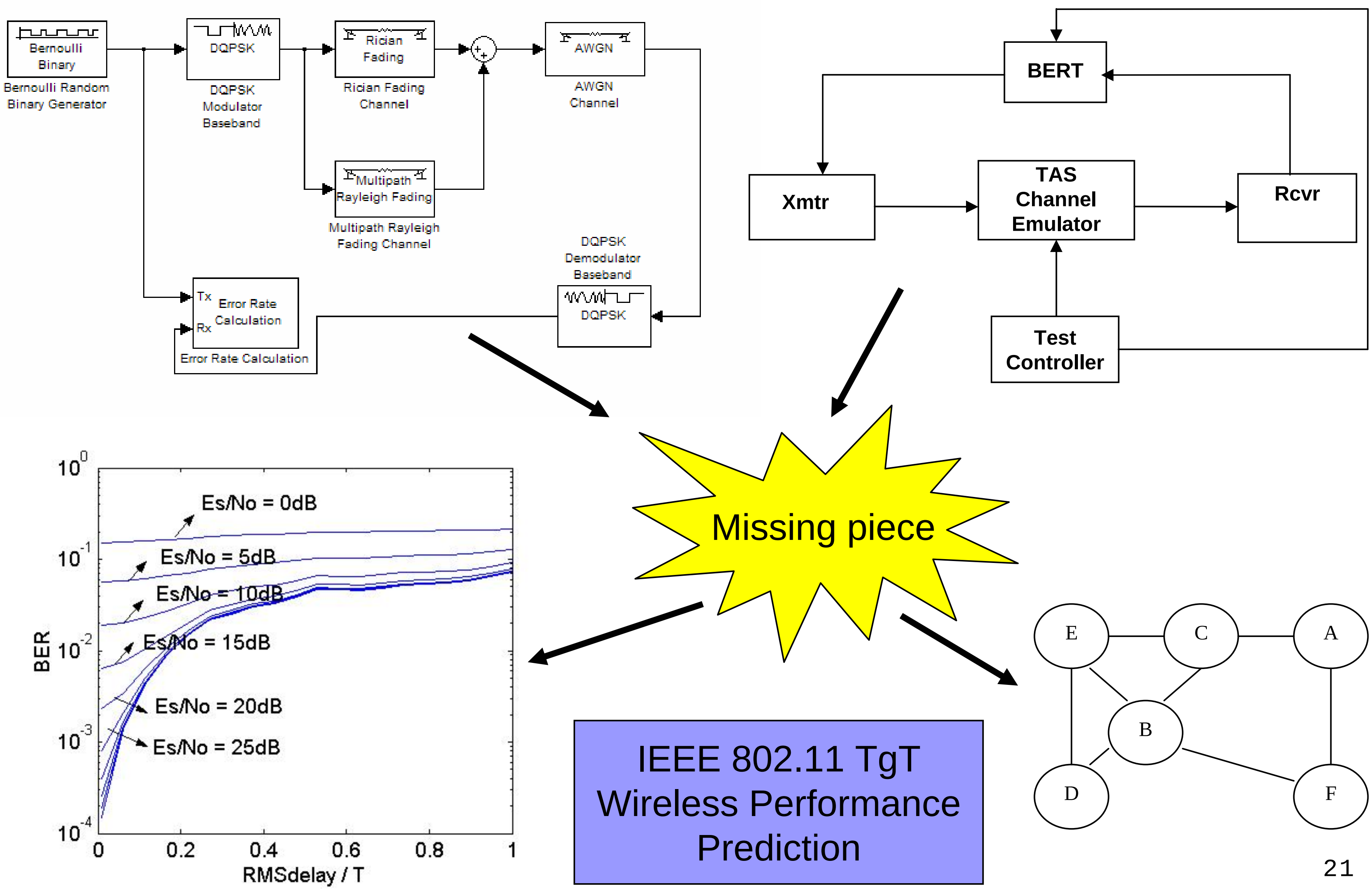


RMSE comparison of adaptive and fixed rate sampling given similar simulation time

Adaptive sampling

- Conclusions
  - Improve the accuracy of the response surface: adaptive sampling can reduce RMSE by between one-tenth and one-quarter given the similar simulation time with traditional fixed rate sampling
  - Reduce the time to generate response surface: the adaptive sampling method can achieve the similar RMSE with between one-quarter and one-third less simulation time compared to traditional fixed rate sampling

Conclusions



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Conclusions

- We proposed alternative methods that overcome limitations of existing methods for representing and evaluating the effect of propagation impairments on the performance of wireless communications systems
- We have shown that polynomial response surface models are a particularly efficient way to completely describe the performance of wireless communications systems as a function of standard channel parameters
- We have also shown that adaptive sampling can be used to significantly reduce the time and effort required to generate a surface response model from physical layer simulations

Recommendations for Future work

- Demonstration of the experimental determination of an response surface model
- Assessment of the potential role of response surface models for visualization and diagnostic purposes
- Development of accuracy requirements for response surface models
- Alternative ways to improve the efficiency of the sampling scheme
- Extension of adaptive sampling to greater than three dimensions

End of presentation