Software-Controlled Mobile Fading Simulator

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Overview

- Motivation
- The mobile fading channel
- Software modeling of fading
- Possible hardware designs
- The chosen design
- Performance results
- Recommendations and conclusions

Motivation

- Want to build a simulator to test mobile devices under real-life conditions (fading channel)
- Current hardware simulators are expensive (tens of 1000's of $$$)
- Difficult to incorporate new fading models into current simulators
- *We want more flexibility than current commerical simulators can provide*

The mobile fading channel

- Multiple paths from transmitter to receiver (reflections, diffraction)
- Items of size at least comparable to λ are of interest — at 1 GHz, this is only 30 cm!
- The *instantaneous* signal-to-noise ratio (SNR) varies (phase cancellation)
- If we assume that received waves come from all directions with the same probability, we find that the envelope probability density function (pdf) is a *Rayleigh* distribution

Software Modeling of Fading

- Characterize the received amplitude by the *Nakagami-m* distribution

$$p_R(r) = \frac{2}{\Gamma(m)}\left(\frac{m}{\Omega}\right)^m r^{2m-1} e^{-mr^2/\Omega}$$

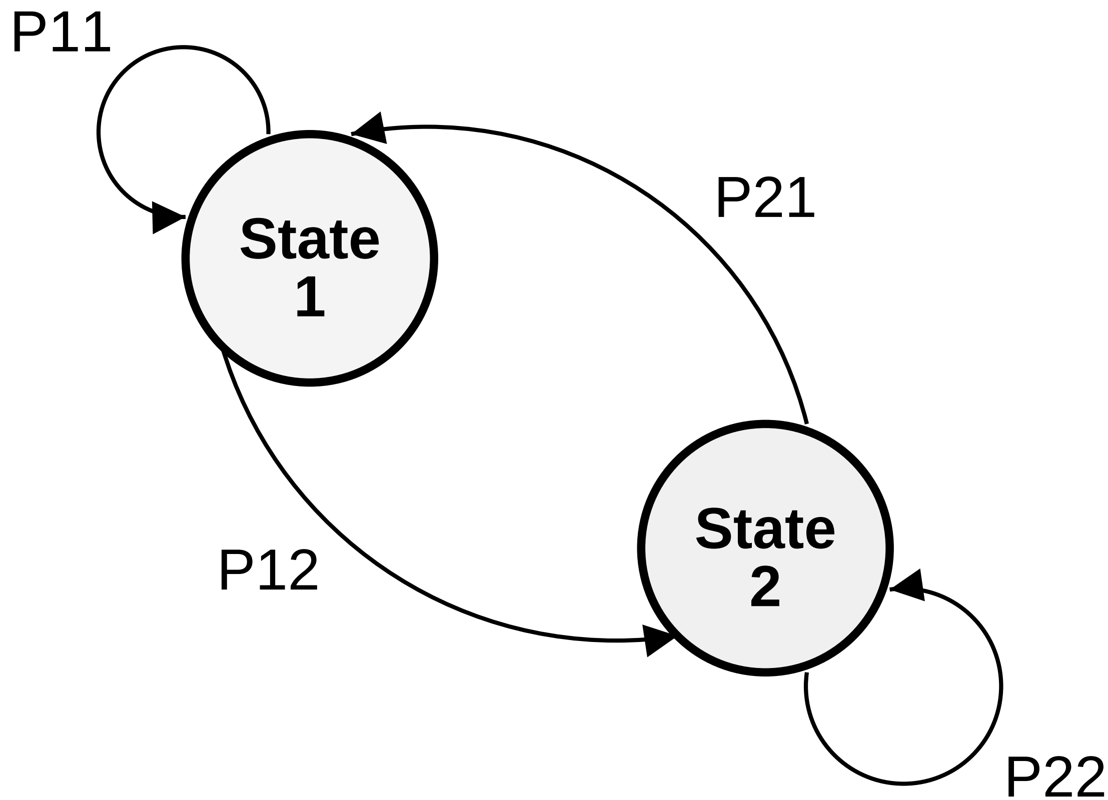
- Includes Rayleigh as a specific case $(m = 1)$

- Need to find a computationally simple model, for simulation purposes

Markov model of the Nakagami-m Fading Channel

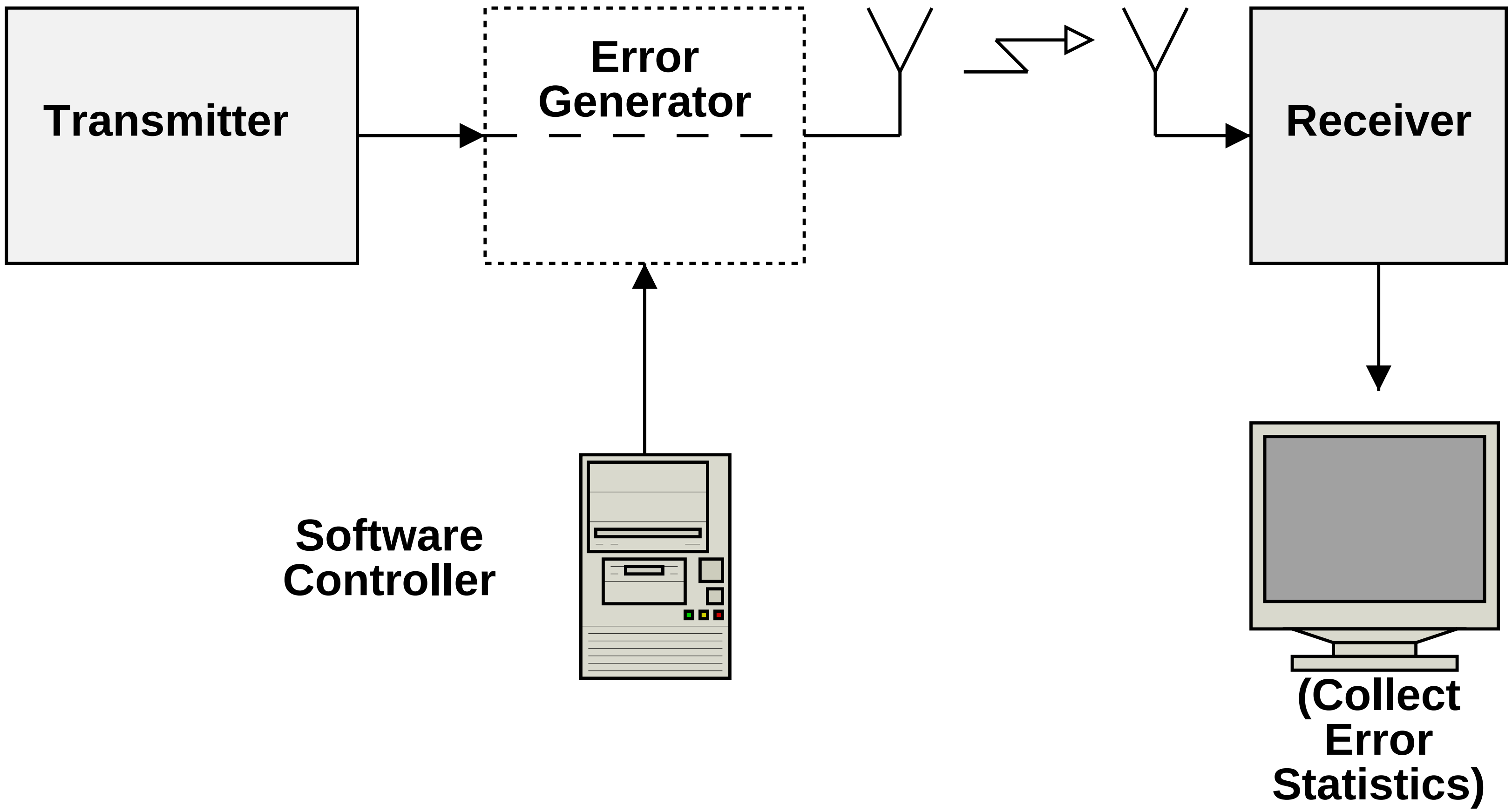
- Divide the envelope pdf into several distinct regions
- Calculate the *average* bit error rate (BER) for each region
- Calculate the *transition probability* from every region to every other region
- Build a Markov chain (similar to a state machine) to describe the states

Markov model (cont'd)



Markov Chain, $n = 2$ states

Hardware Fading Testing



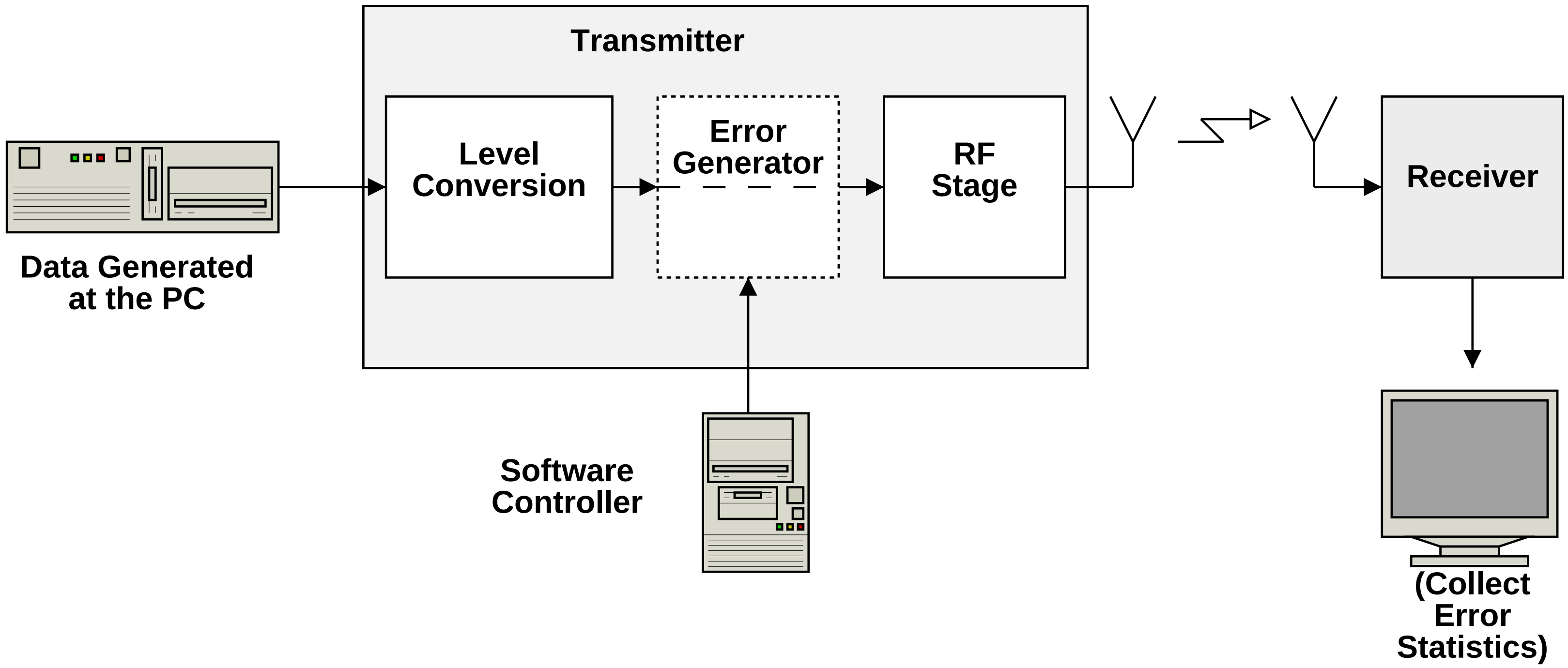
Fading Simulator Hardware Design — Constraints

- Fading simulated at the transmitter — don't want to modify receiver equipment
- Minimum modification to transmitter hardware
- Software controllable
- Real-time, "online" simulation
- Should be transparent to equipment under test

Possible Hardware Designs

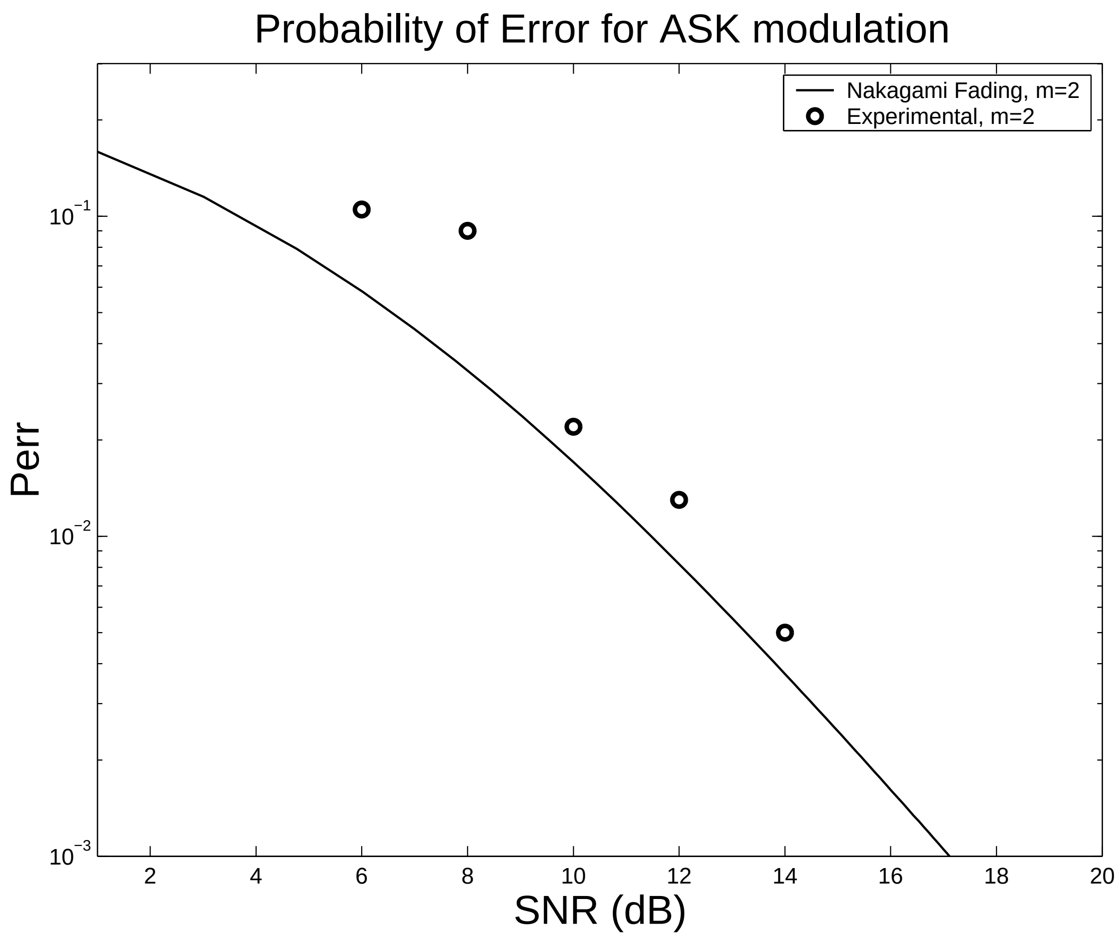
- Mismatch circuits at the transmit antenna — divert some power from the antenna. Use transmission lines
- Voltage-controllable attenuator/amplifier (at RF frequencies)
- Interface at the bitstream of the transmitter

Chosen Hardware Design



TLP/RLP ASK Radio. 434 MHz. 2400 bps. Interfaced to PC Serial port.

Performance Results



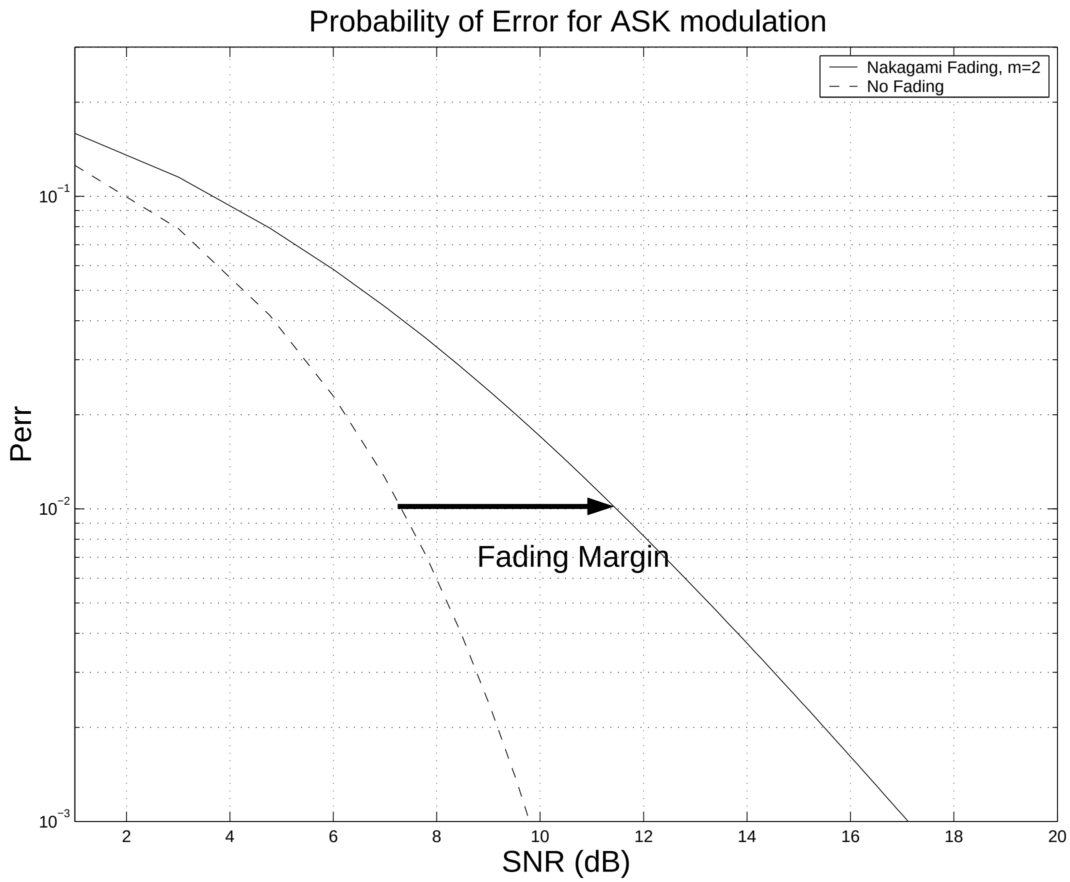
Recommendations

- Bit-level interface is suboptimal
- Preferred method would be at RF frequencies — requires microwave circuit techniques
- Commercial application would use a voltage-controlled, variable attenuator connected to a real-time PC or embedded microcontroller

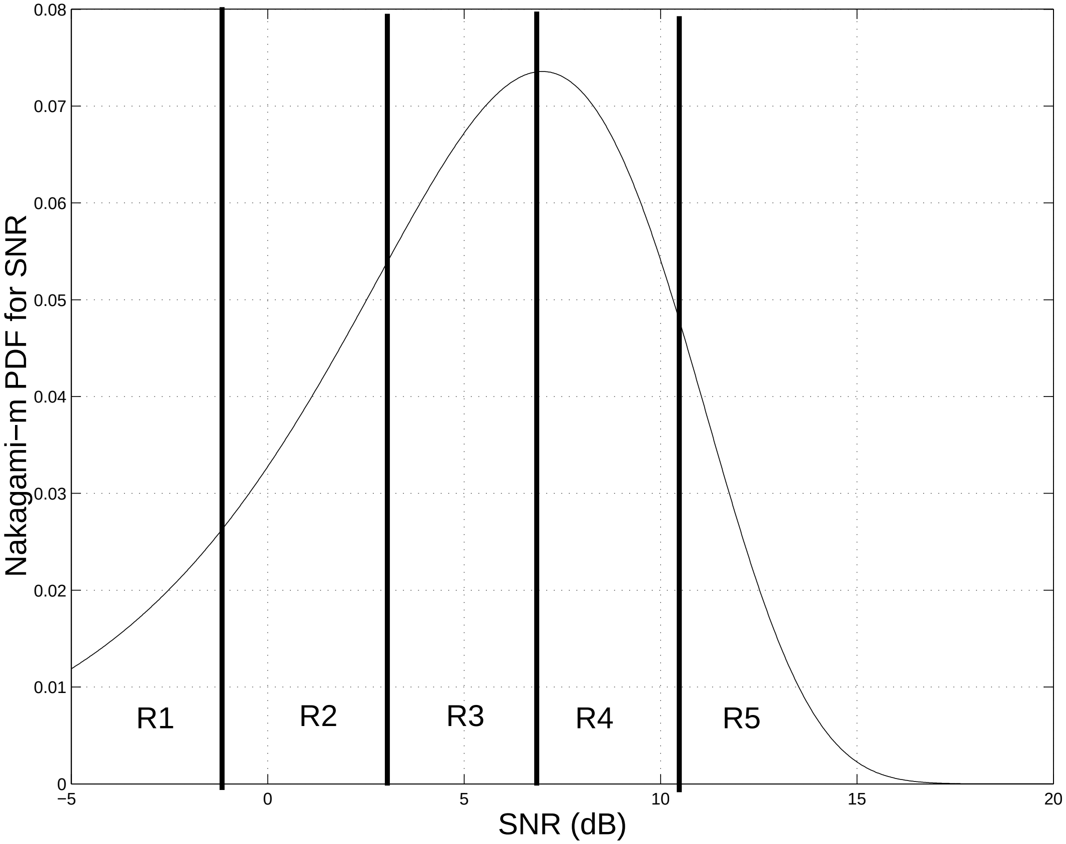
Conclusions

- A software-controlled hardware fading simulator has been constructed
- Test results show that the simulator is working properly
- Software control allows flexibility in the error model used
- Easily reconfigurable for different test conditions

Fading Margin



Partitioned Nakagami-m Distribution



Markov model (cont'd)

For n levels, we need to solve for the BERs of each level

$$h_i = \frac{\int_{\gamma_i}^{\gamma_{i+1}} P_{err}(\gamma) P_{SNR}(\gamma, m, \bar{\gamma}) d\gamma}{\int_{\gamma_i}^{\gamma_{i+1}} P_{SNR}(\gamma, m, \bar{\gamma}) d\gamma}$$

and the transition probabilities

$$\tau_{i,j} = \int_{\gamma_i}^{\gamma_{i+1}} \int_{\gamma_j}^{\gamma_{j+1}} P_{SNR,joint}(\alpha, \bar{\gamma}, \beta, \bar{\gamma} | m, \rho) d\alpha d\beta$$

where ρ is the correlation, and $P_{SNR,joint}$ is the joint pdf of two Nakagami-m random variables

Markov model (cont'd)

Determining the optimal thresholds for each of the n levels is a complex optimization problem.
We will use the sub-optimal method of attempting to equate the *residency probabilities*

$$P_{\text{residency},i} = \int_{\gamma_i}^{\gamma_{i+1}} p_{\text{Nakagami}}(\gamma, m, \bar{\gamma}) d\gamma$$

Licensing in 433.92 MHz Band

- 433.05—434.79 MHz is licensed in Canada as an Industrial, Scientific, and Medical (ISM) band (reference: http://strategis.ic.gc.ca/SSI/sf/cane.pdf, section S5.138)

- The ITU (International Telecommunication Union) has specifications for radiation limits, spectral masks, etc (reference: http://www.itu.int/)