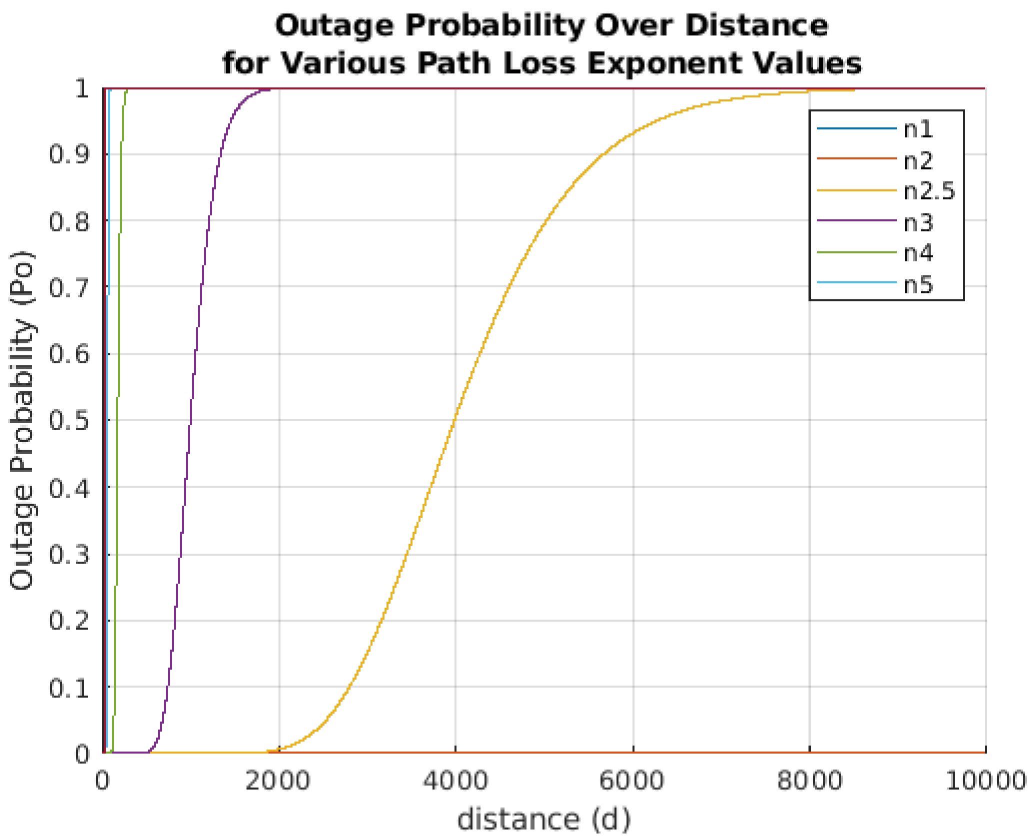
ee597-assignment2

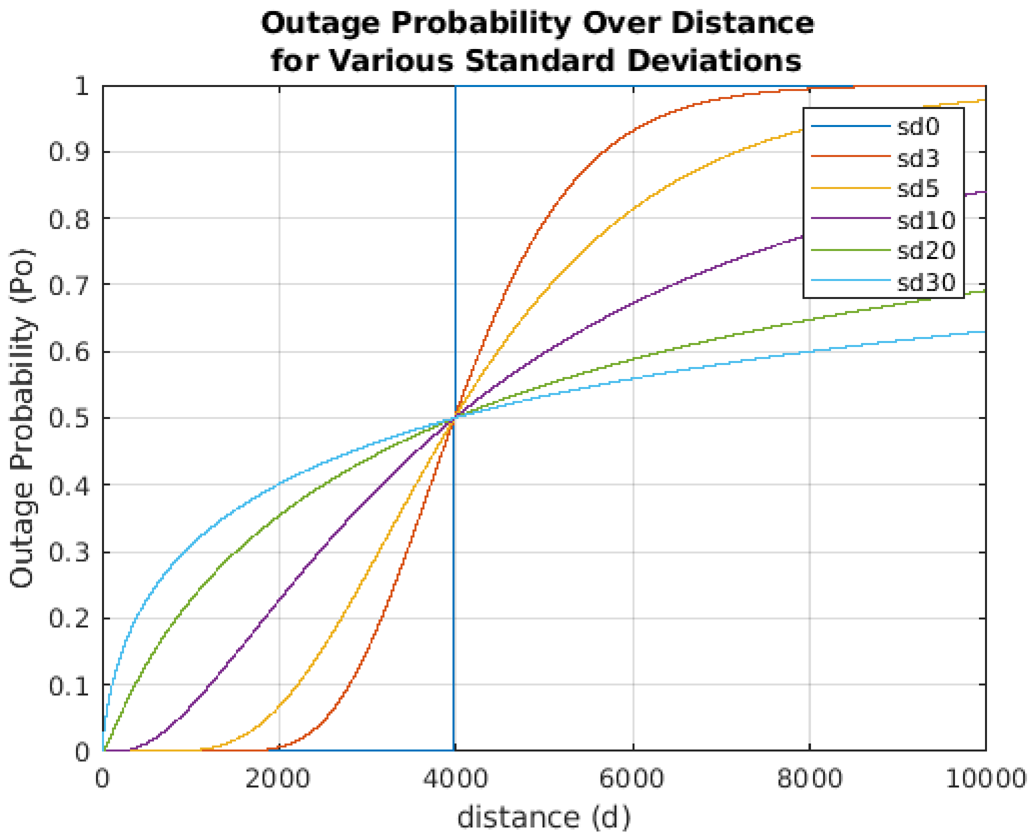
Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by
Bill Wang student id:
and
Spencer McDonough student id:

Outage Probability as a function of distance for Log-Normal Shadowing



We can see that the probability of outage sigmoid function gets skewed left as we increase the value of the path loss exponent (PLE). This means that the probability of outage increases exponentially by a greater factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment (heta > 2 : loss, heta = 2 : vacuum, or no loss, heta < 2 : gain).



We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponenent (PLE) increases. This makes sense, as the probability of outage is inversely proportional to the log of the PLE's standard deviation.

Rate Adaptation

![*Figure 3: Effective Goodput (Mbps) as a function of SNR*]# ee597-assignment2 Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

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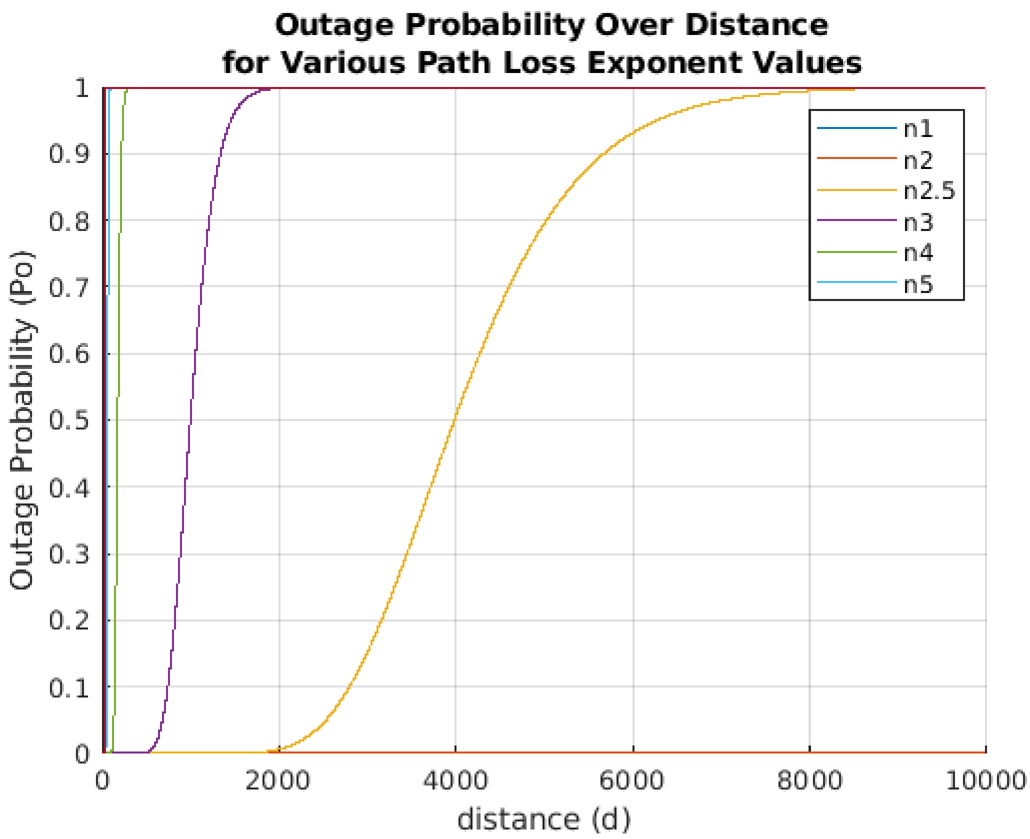

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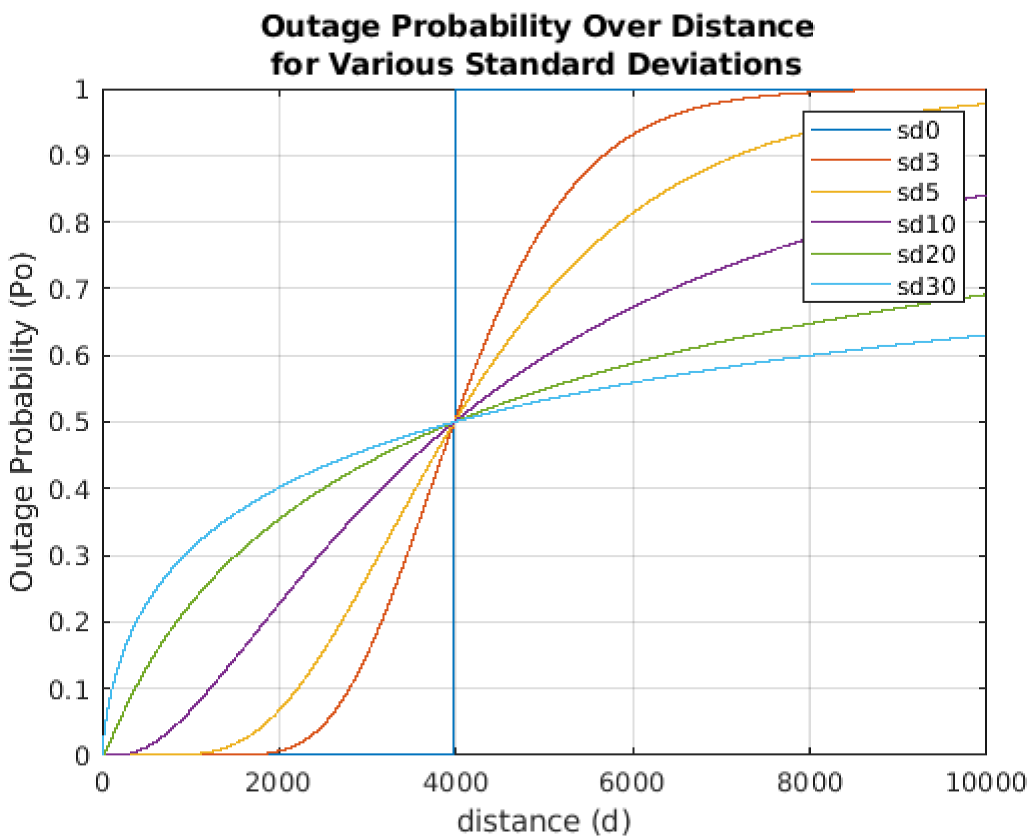

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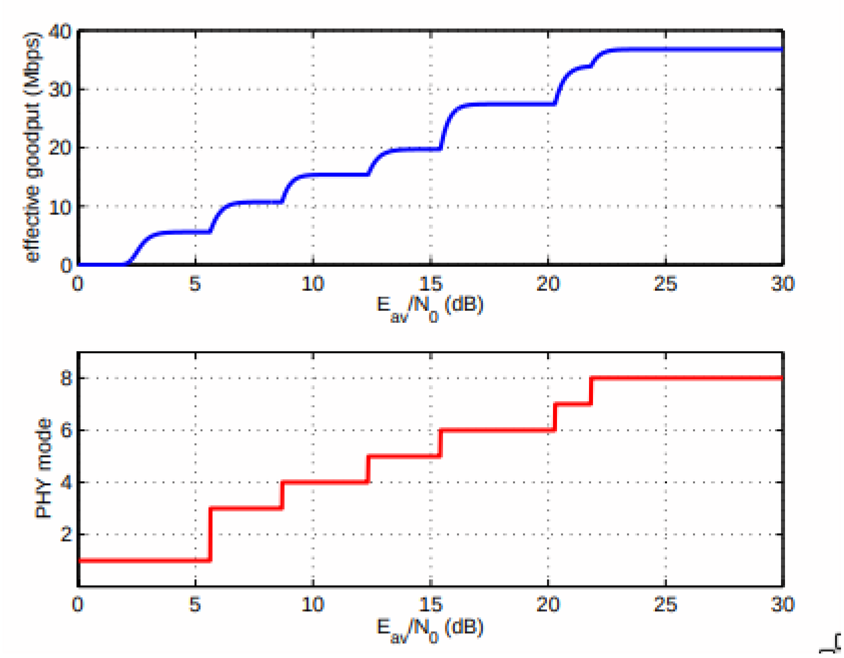


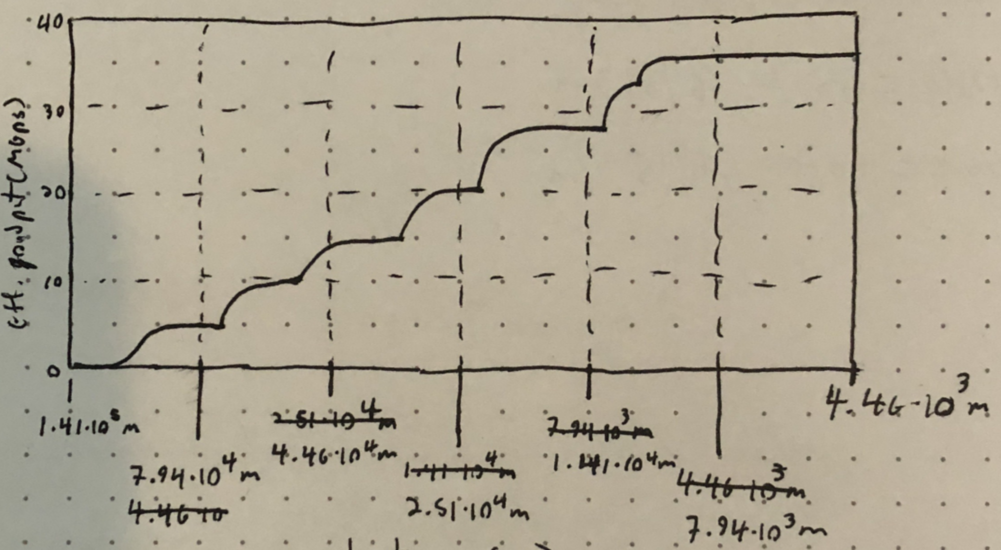
Effective Goodput as a Function of Distance

$SNR_{dBm} = P_{r\,dBm} - N_{dBm}$

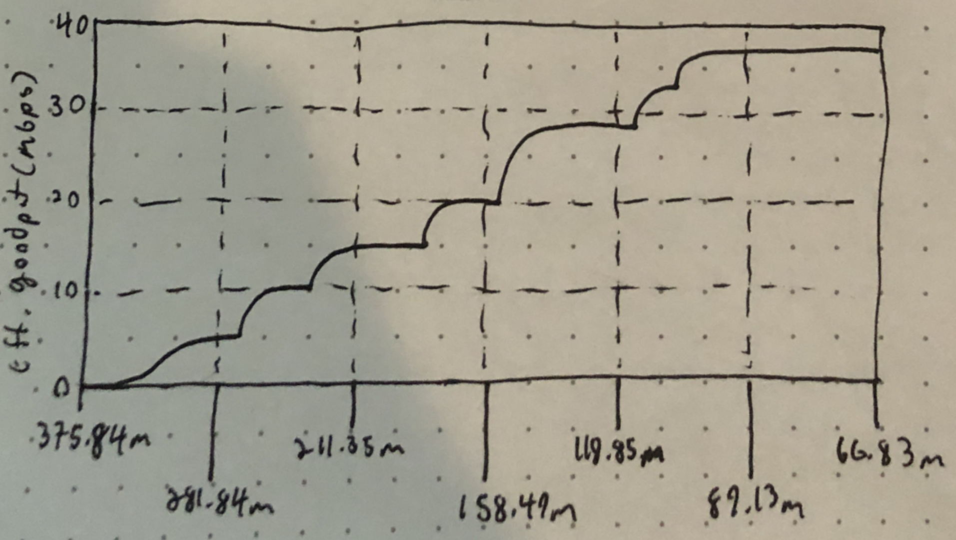
$P_{r\,dBm} = P_{T\,dBm} + K_{ref\,dBm} - \eta \cdot 10\log_{10}(\frac{d}{d_0})$

$\therefore d = d_0 \cdot 10^{\left[\frac{P_{T\,dBm} + K_{ref\,dBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10}\right]}$

$\therefore$ Effective Goodput (d) for $\underline{\eta = 2}$, $P_{T\,dBm} = 23dBm$, $K_{ref\,dBm} = -10dBm$, $N_{dBm} = -90dBm$.



$\therefore$ Effective Goodput for $\underline{\eta = 4}$:



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heta = 2:
d(SNR = 0) = 1.41E5m
d(SNR = 5) = 7.94E4m
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d(SNR = 15) = 2.51E4m
d(SNR = 20) = 1.41E4m
d(SNR = 25) = 7.94E3m
d(SNR = 30) = 4.46E3m

heta = 4:
d(SNR = 0) = 375.84m
d(SNR = 5) = 281.84m
d(SNR = 10) = 211.35m
d(SNR = 15) = 158.49m
d(SNR = 20) = 118.85m
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d(SNR = 30) = 66.83m

Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

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mobile speed = 0:
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p01 = 0.1400
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mobile speed = 25:
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(eff_goodput_vs_snr.png)

ee597-assignment2

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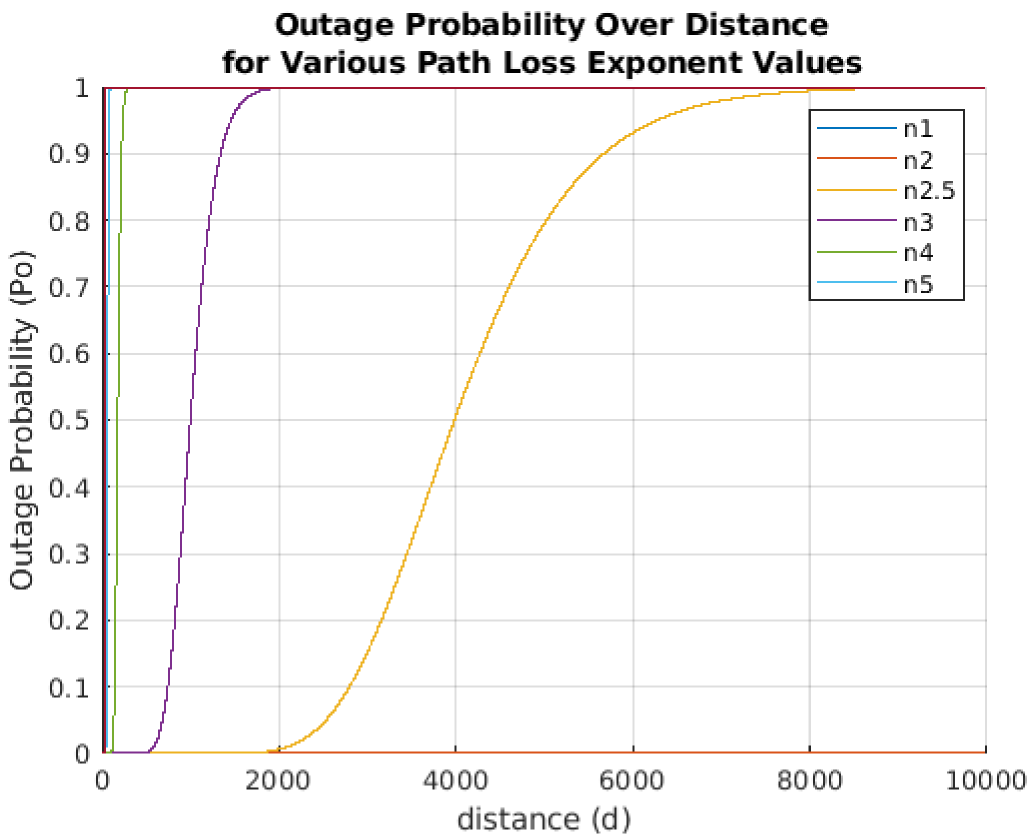

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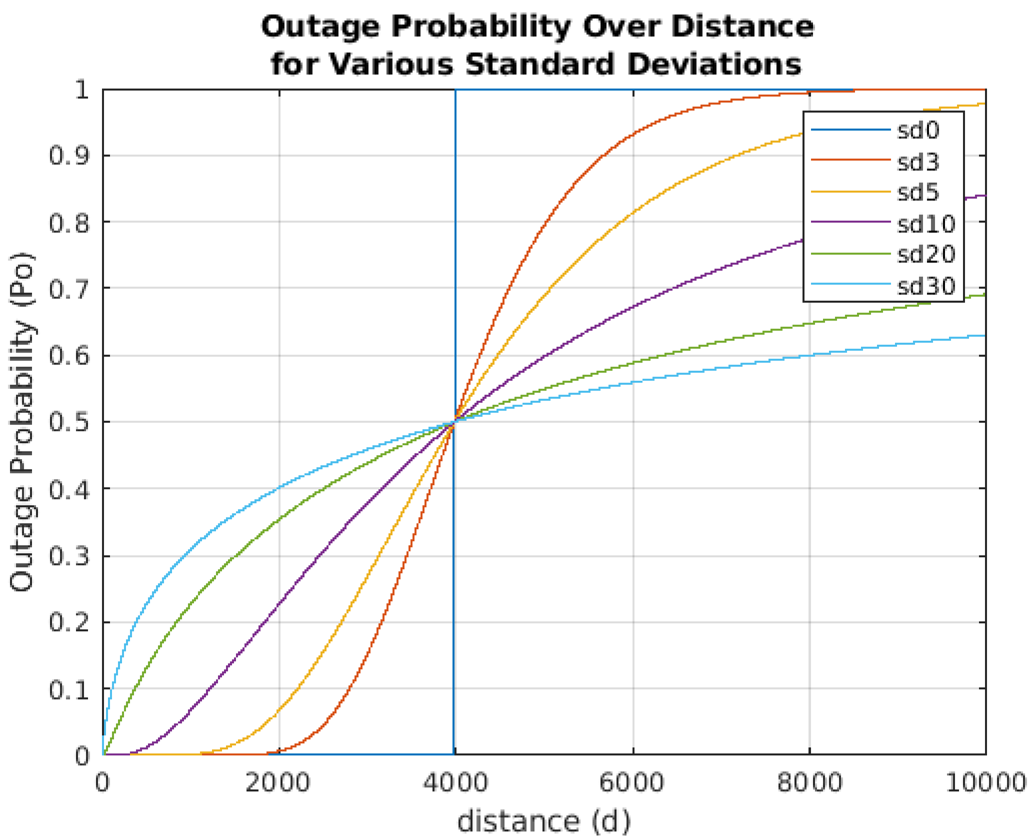

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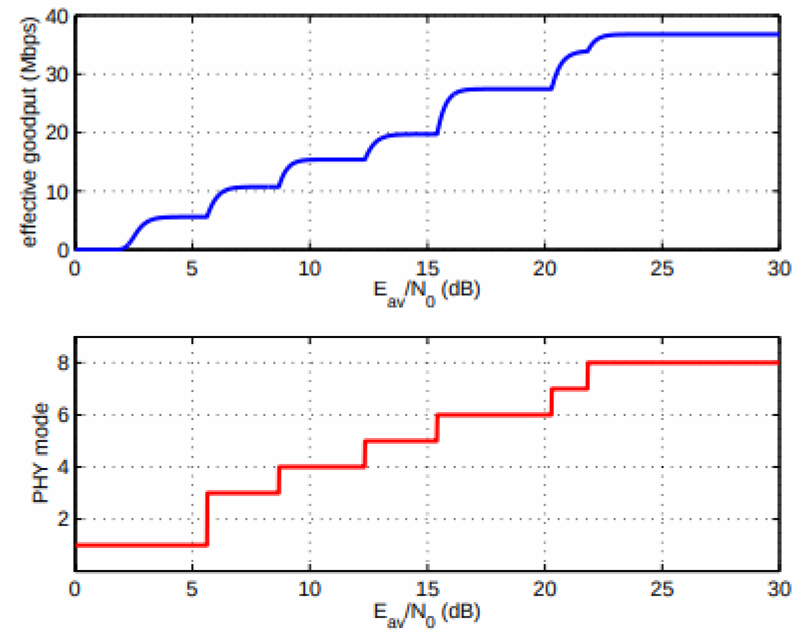
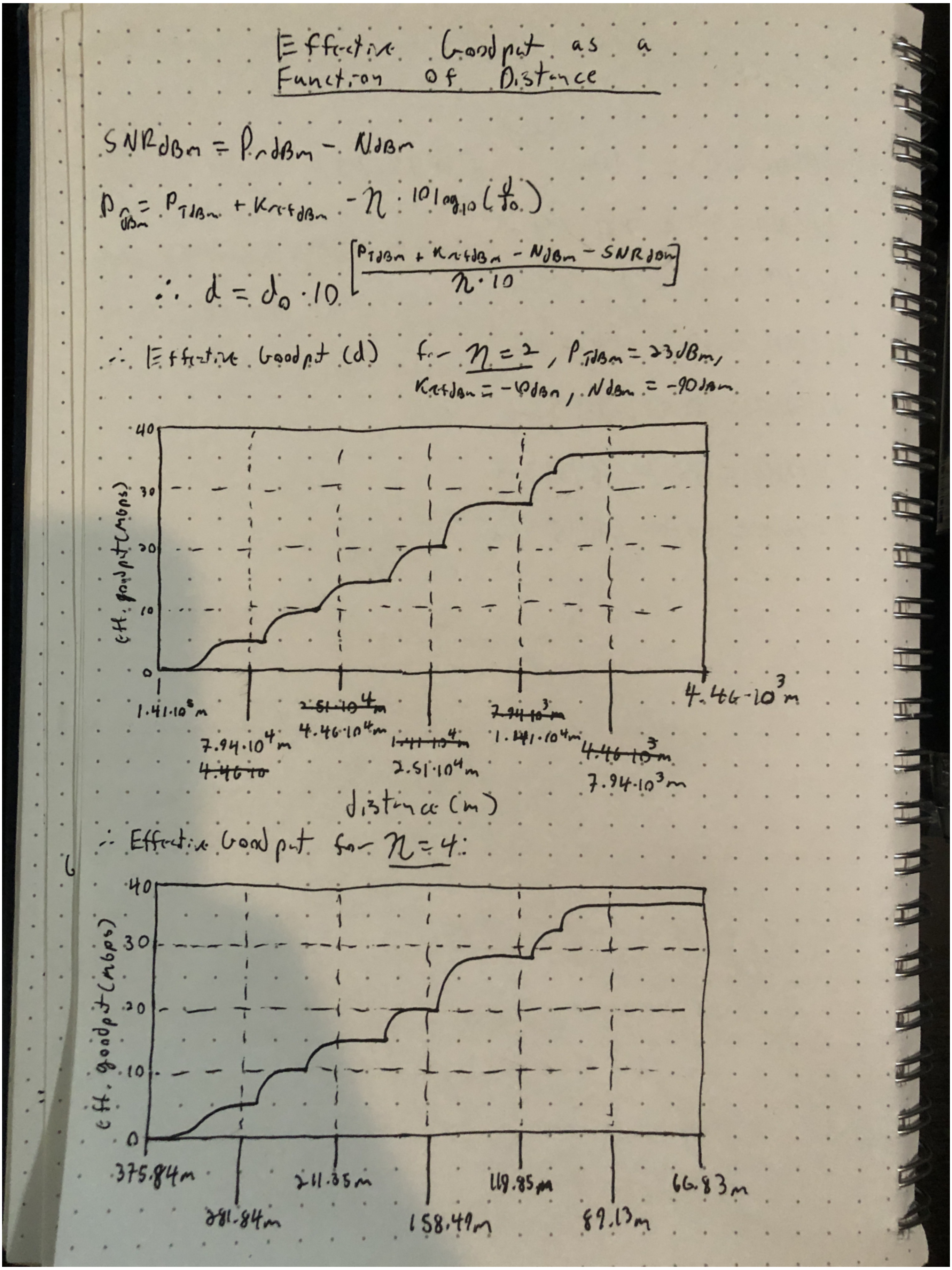
Rate Adaptation





In this exercise, we converted SNR to distance with a known path loss model. P_TdBm = 23dBm, P_{ref} = -10dBm, NdBm = -90dBm. We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with heta values 2 and 4. Here is a breakdown of the SNR --> d(m) conversions for clarity: d = d0 * $10^{(PTdbm\ +\ Pref\ -\ NdBm\ -\ SNRdBm)/(heta\ *\ 10)}$

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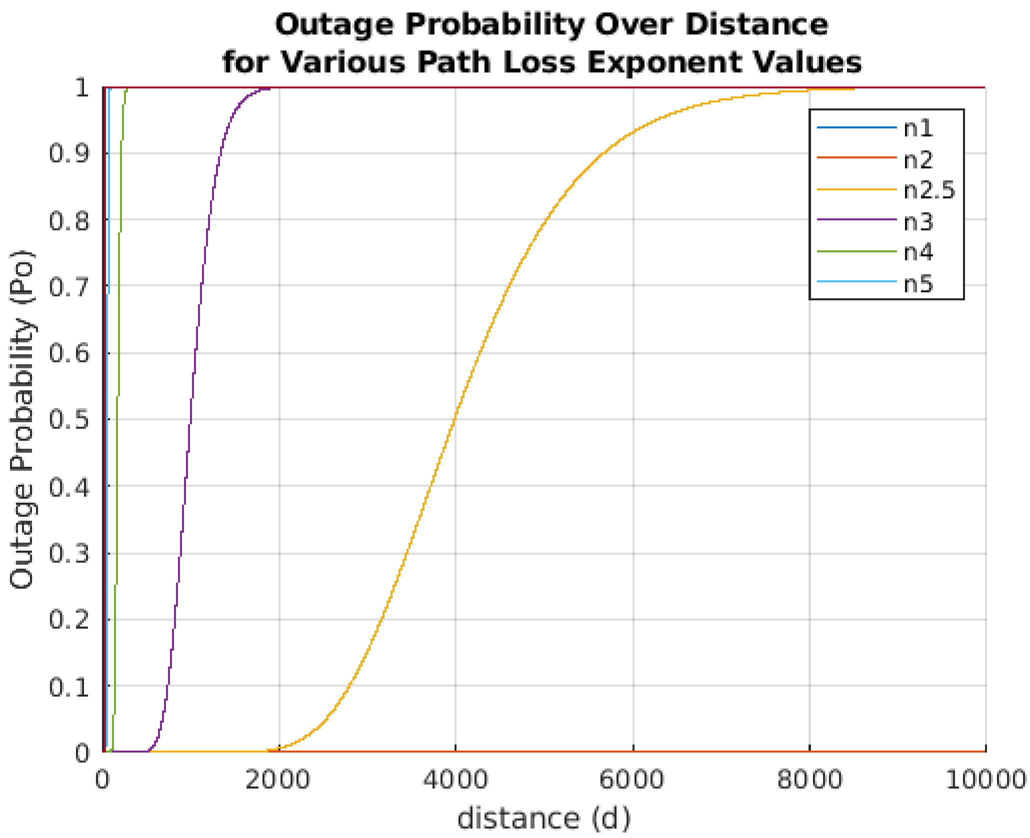

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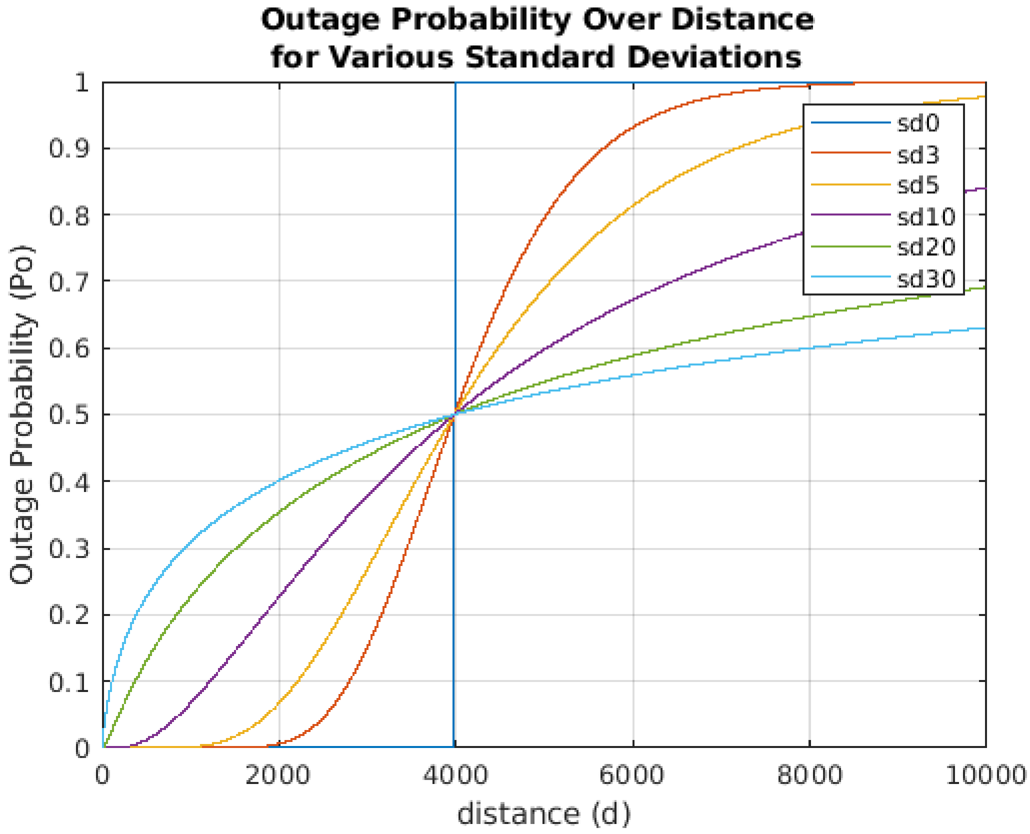

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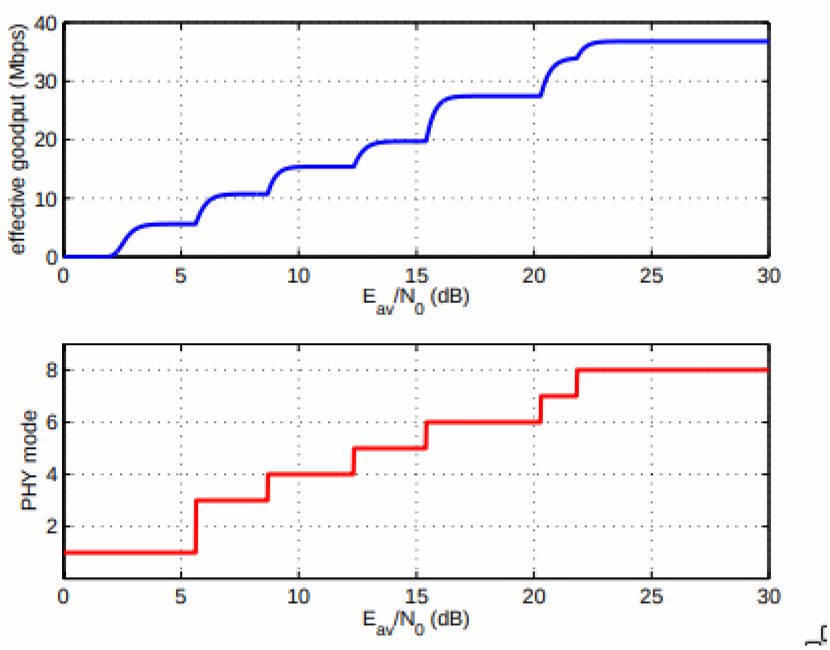

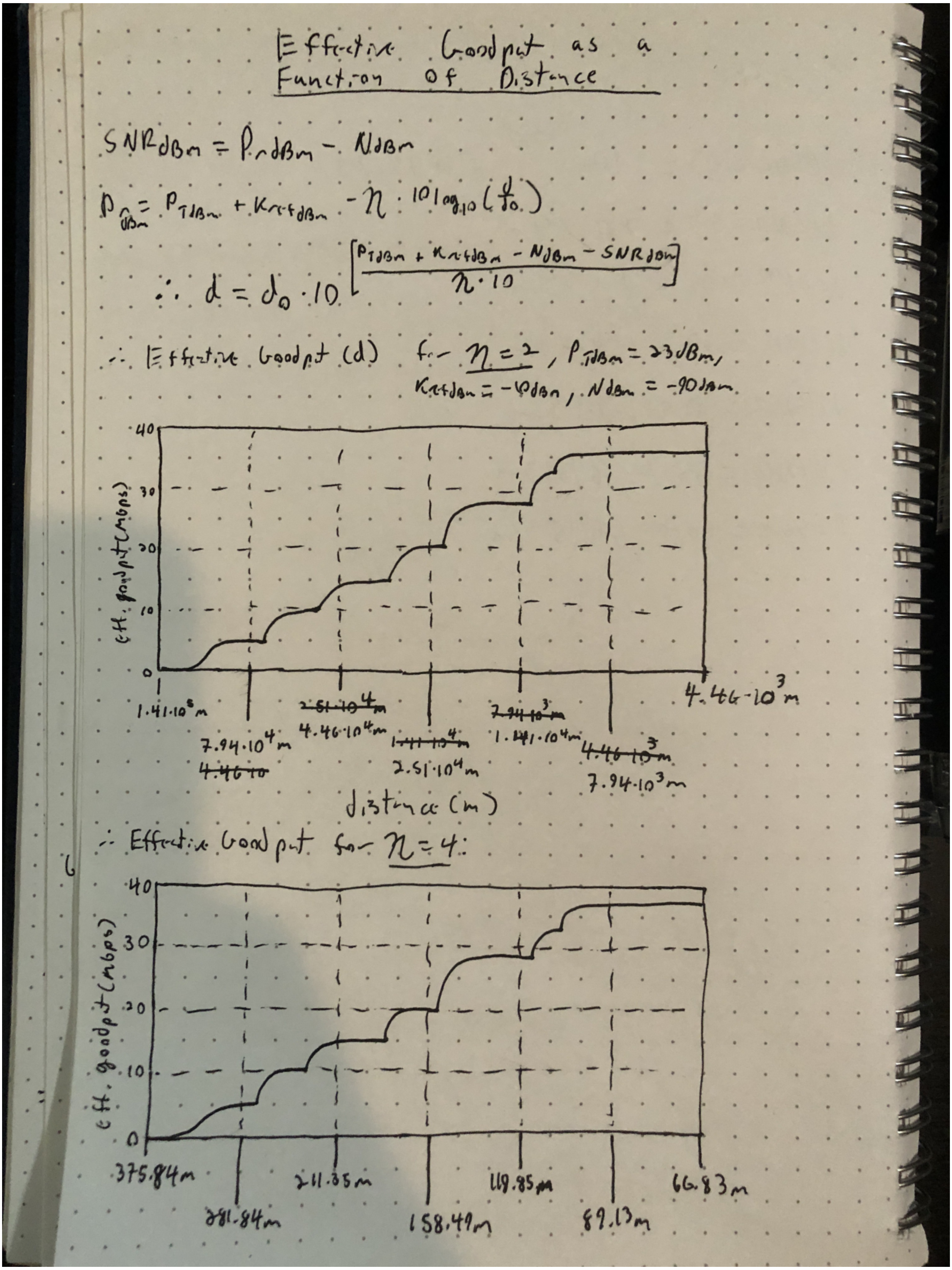

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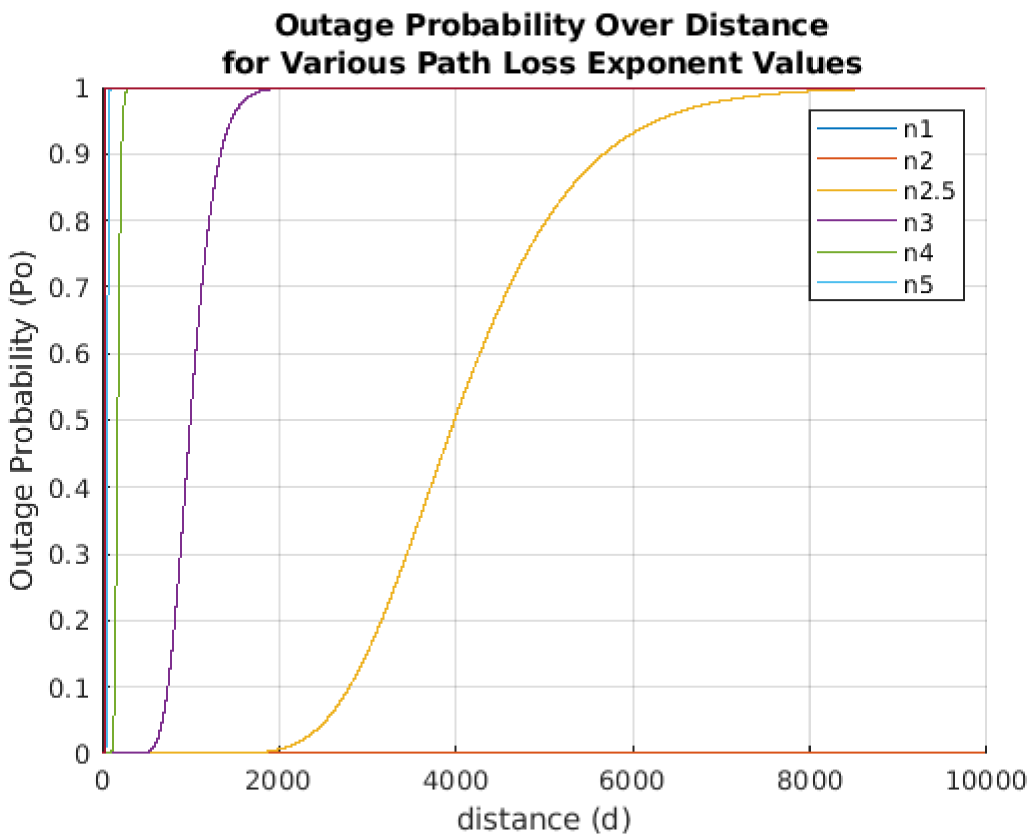

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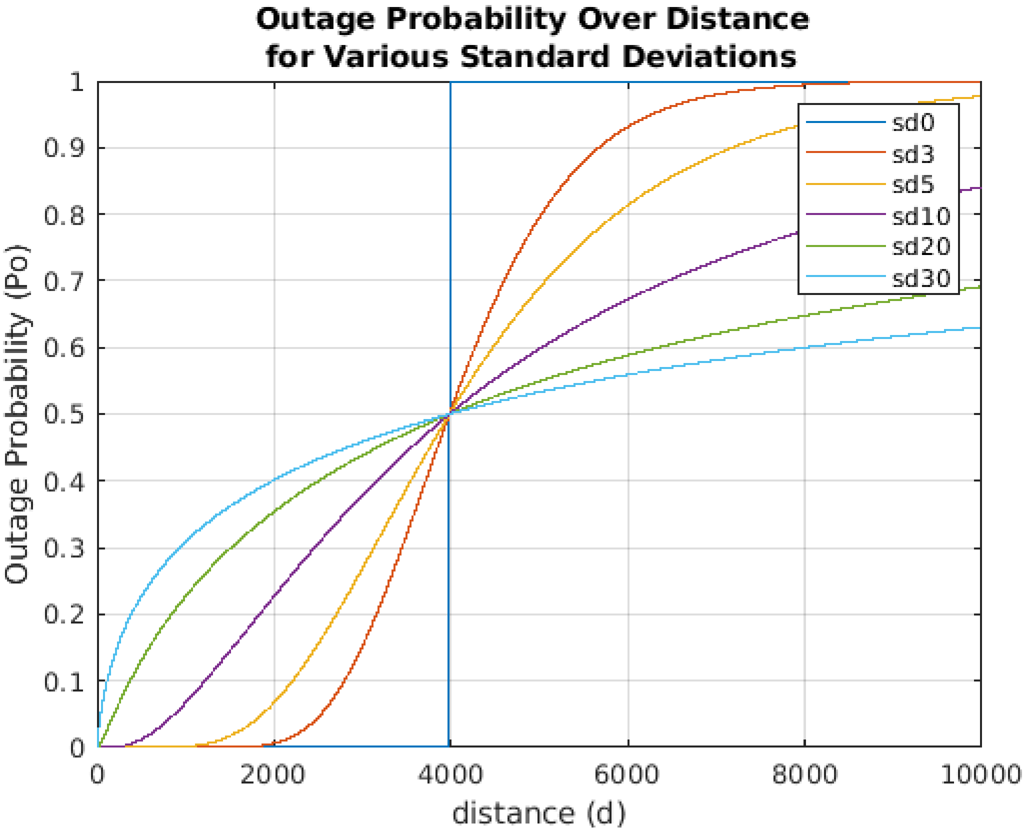

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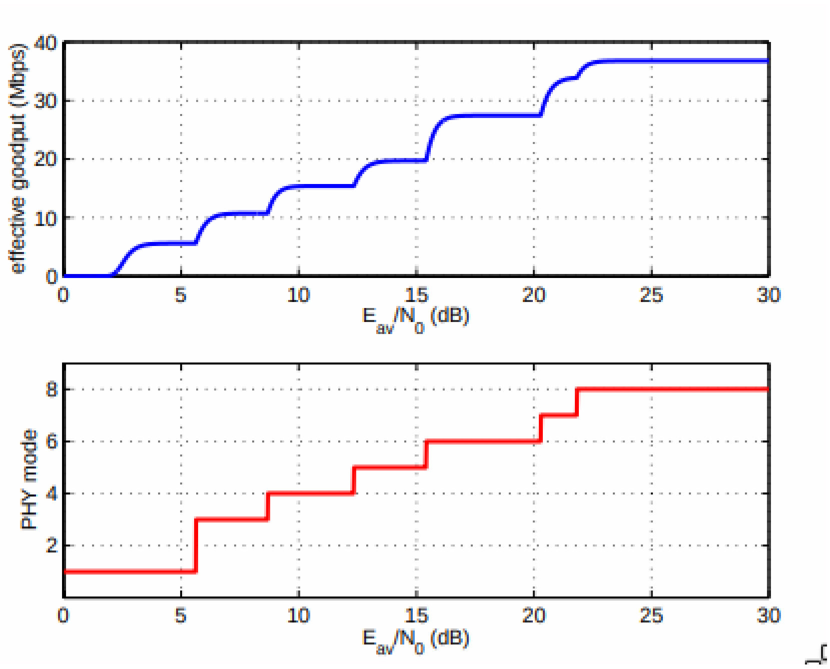

Effective Goodput as a Function of Distance

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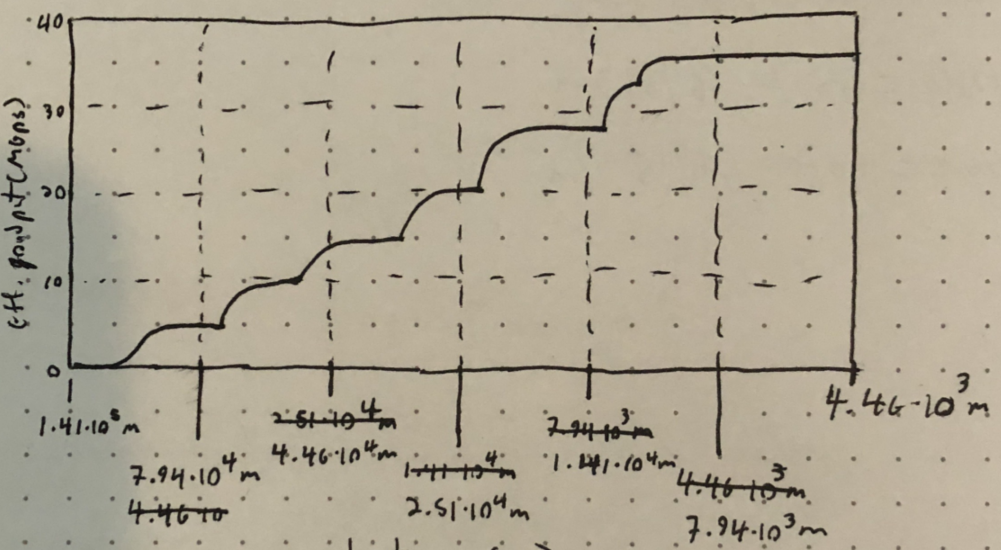
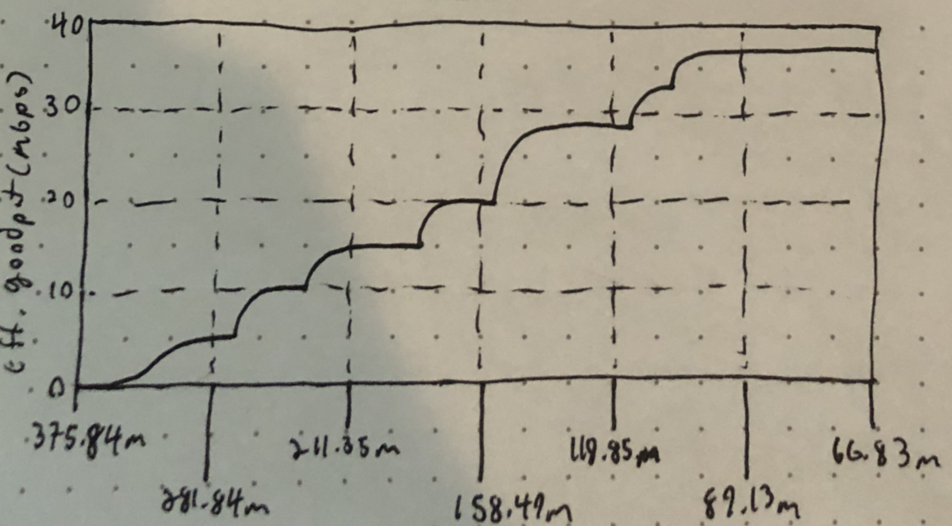
$$\therefore d = d_0 \cdot 10^{\left[\frac{P_{T\,dBm} + K_{ref\,dBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10}\right]}$$

$\therefore$ Effective Goodput (d) for $\eta = 2$, $P_{T\,dBm} = 23dBm$, $K_{ref\,dBm} = -10dBm$, $N_{dBm} = -90dBm$



$\therefore$ Effective Goodput for $\eta = 4$:



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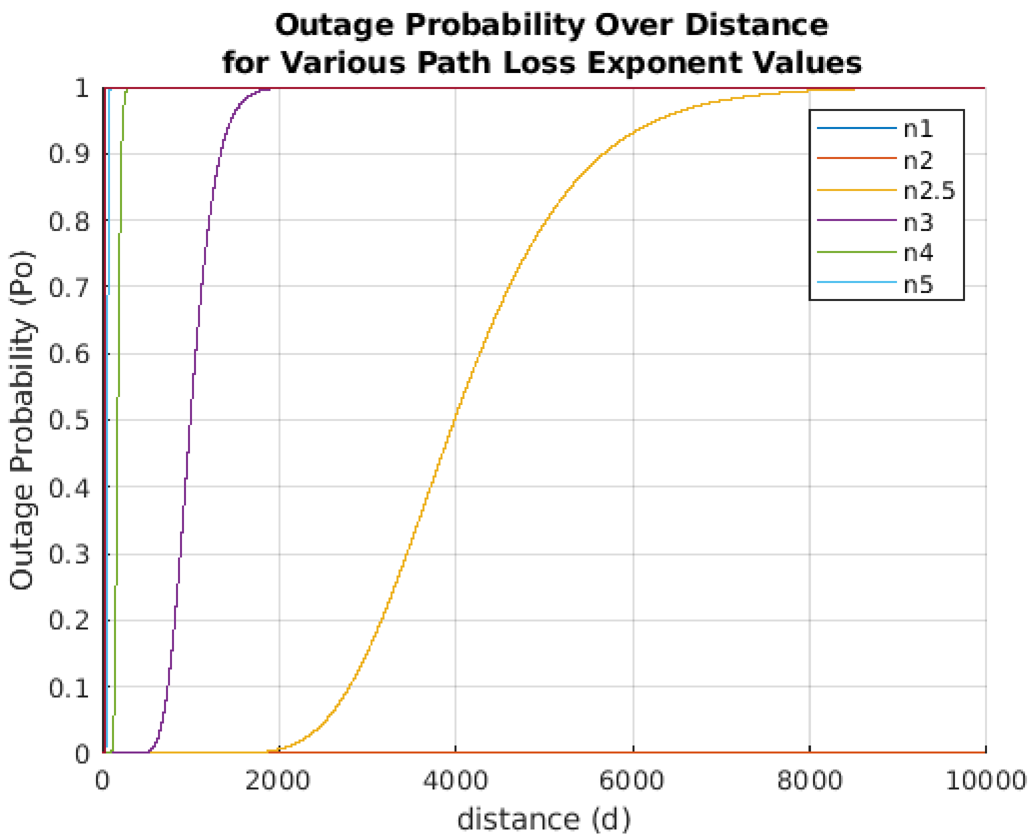

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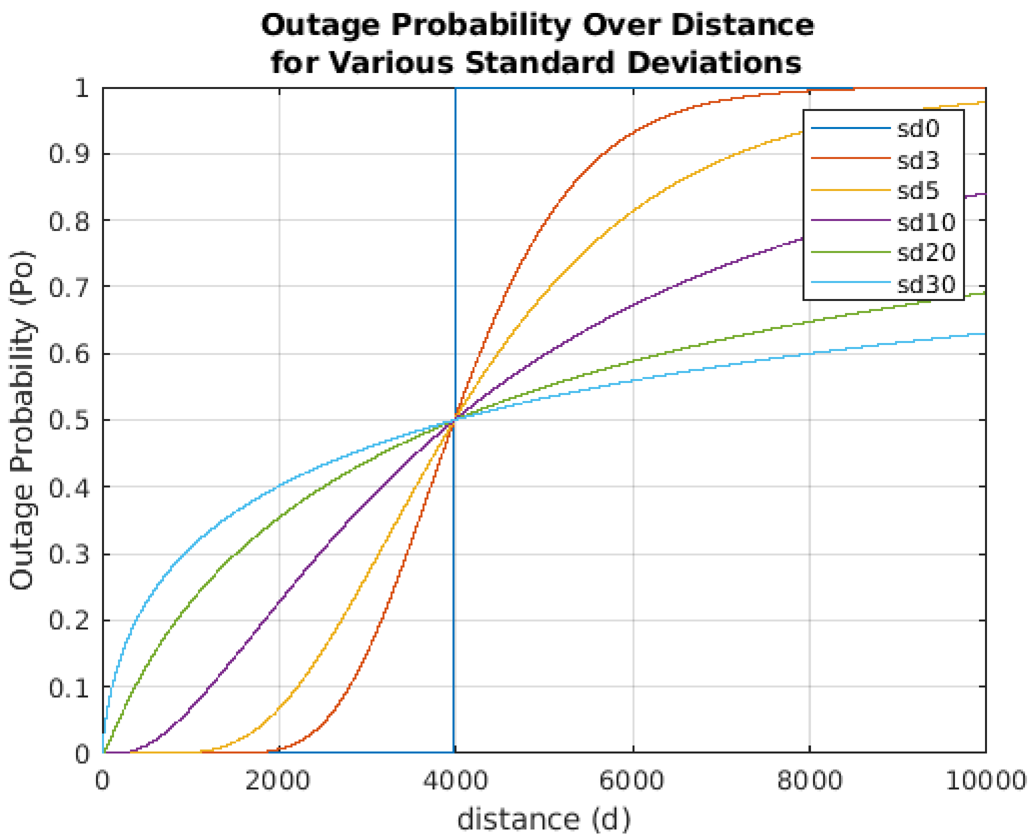

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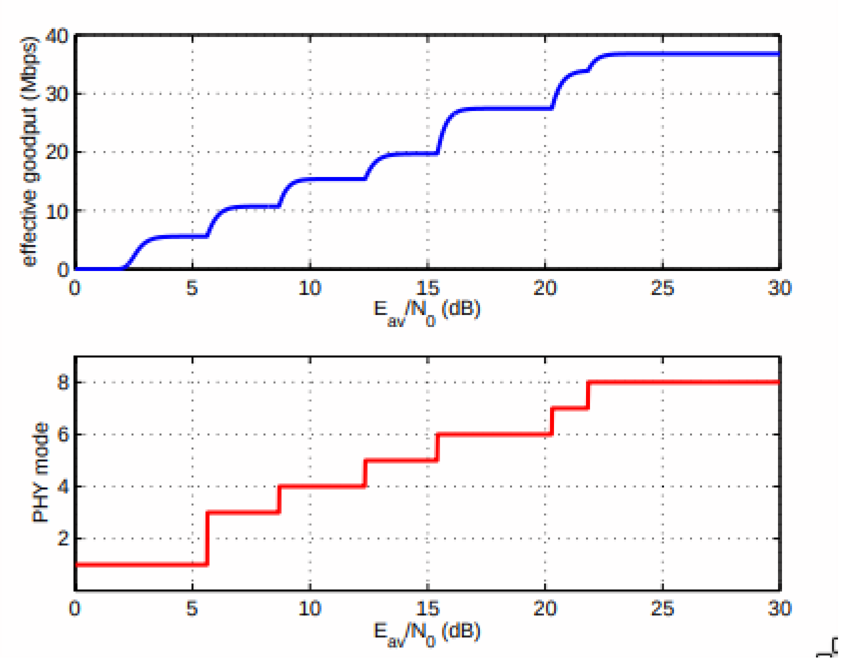

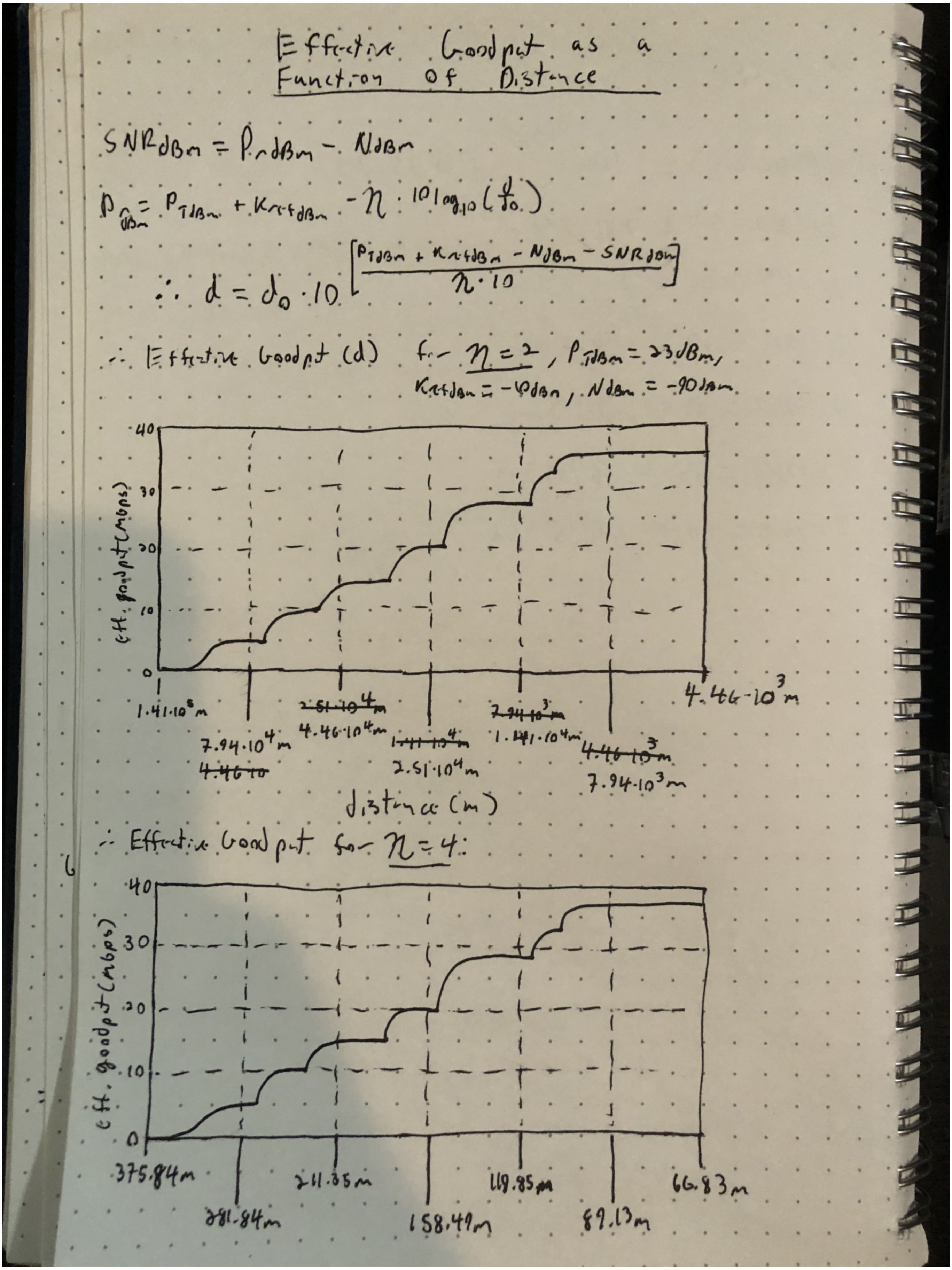

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p11 = 0.6420

mobile speed = 5:
p00 = 0.0775
p01 = 0.1490
p10 = 0.1490
p11 = 0.6240

mobile speed = 10:
p00 = 0.0715
p01 = 0.1430
p10 = 0.1425
p11 = 0.6425

mobile speed = 15:
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p01 = 0.1570
p10 = 0.1575
p11 = 0.6195

mobile speed = 20:
p00 = 0.0750
p01 = 0.1420
p10 = 0.1420
p11 = 0.6405

mobile speed = 25:
p00 = 0.0810
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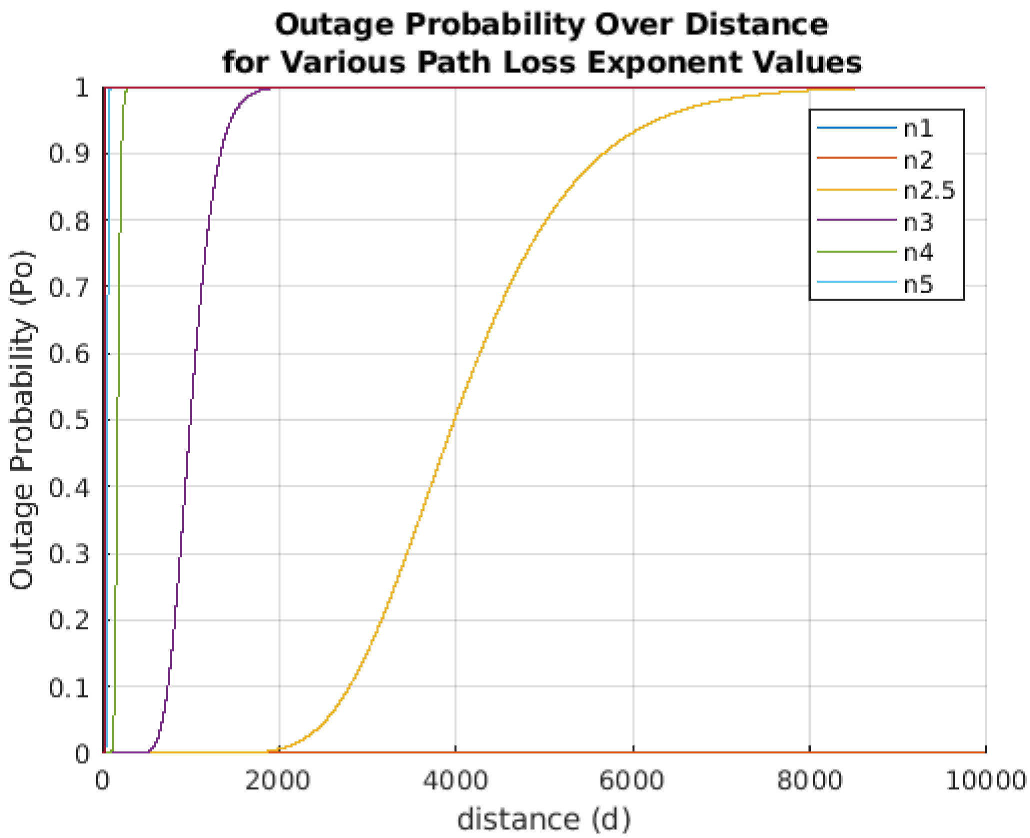
p10 = 0.1485
p11 = 0.6215

ee597-assignment2

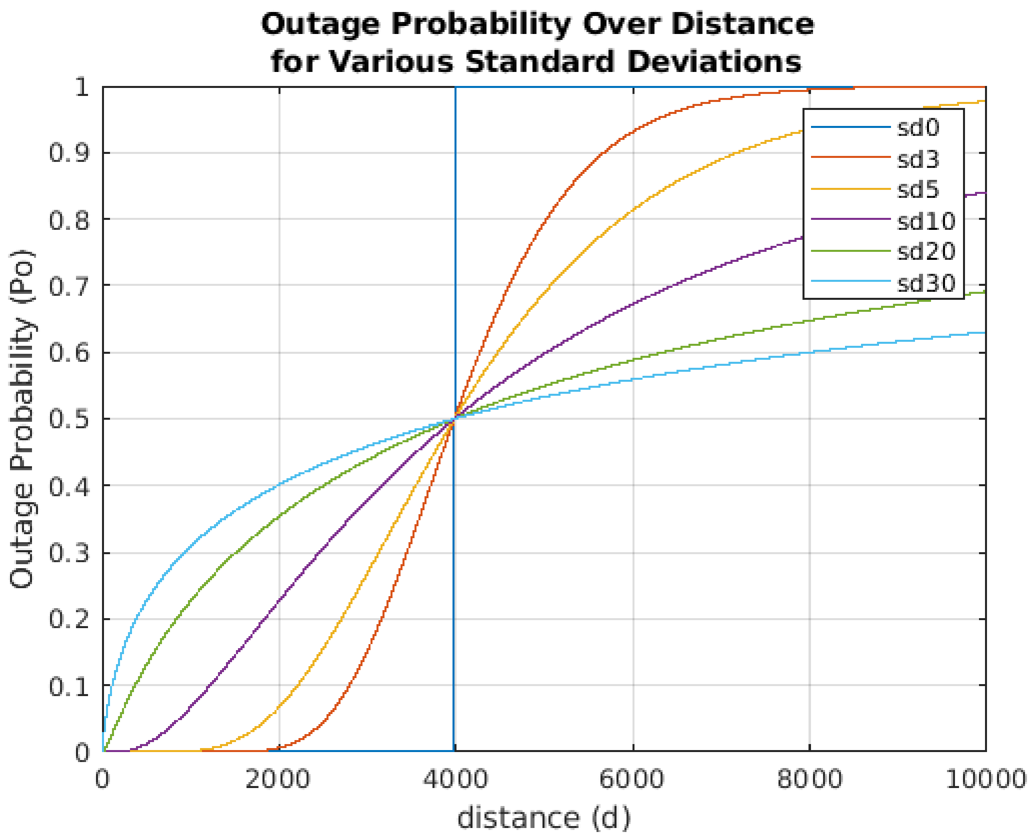
Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by
Bill Wang student id: and Spencer McDonough student id:

Outage Probability as a function of distance for Log-Normal Shadowing



We can see that the probability of outage sigmoid function gets skewed left as we increase the value of the path loss exponent (PLE). This means that the probability of outage increases exponentially by a greater factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment (heta > 2 : loss, heta = 2 : vacuum, or no loss, heta < 2 : gain).



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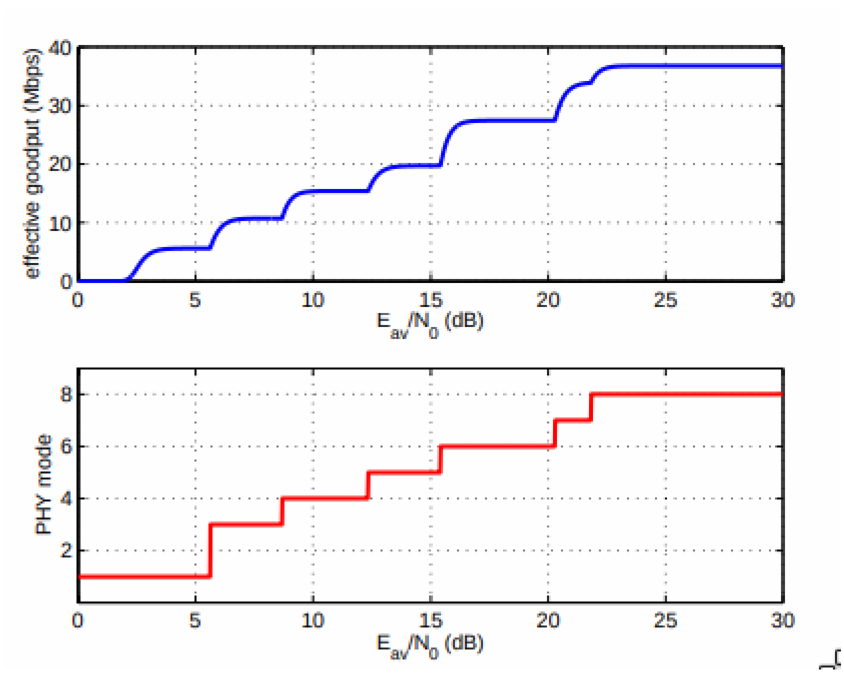
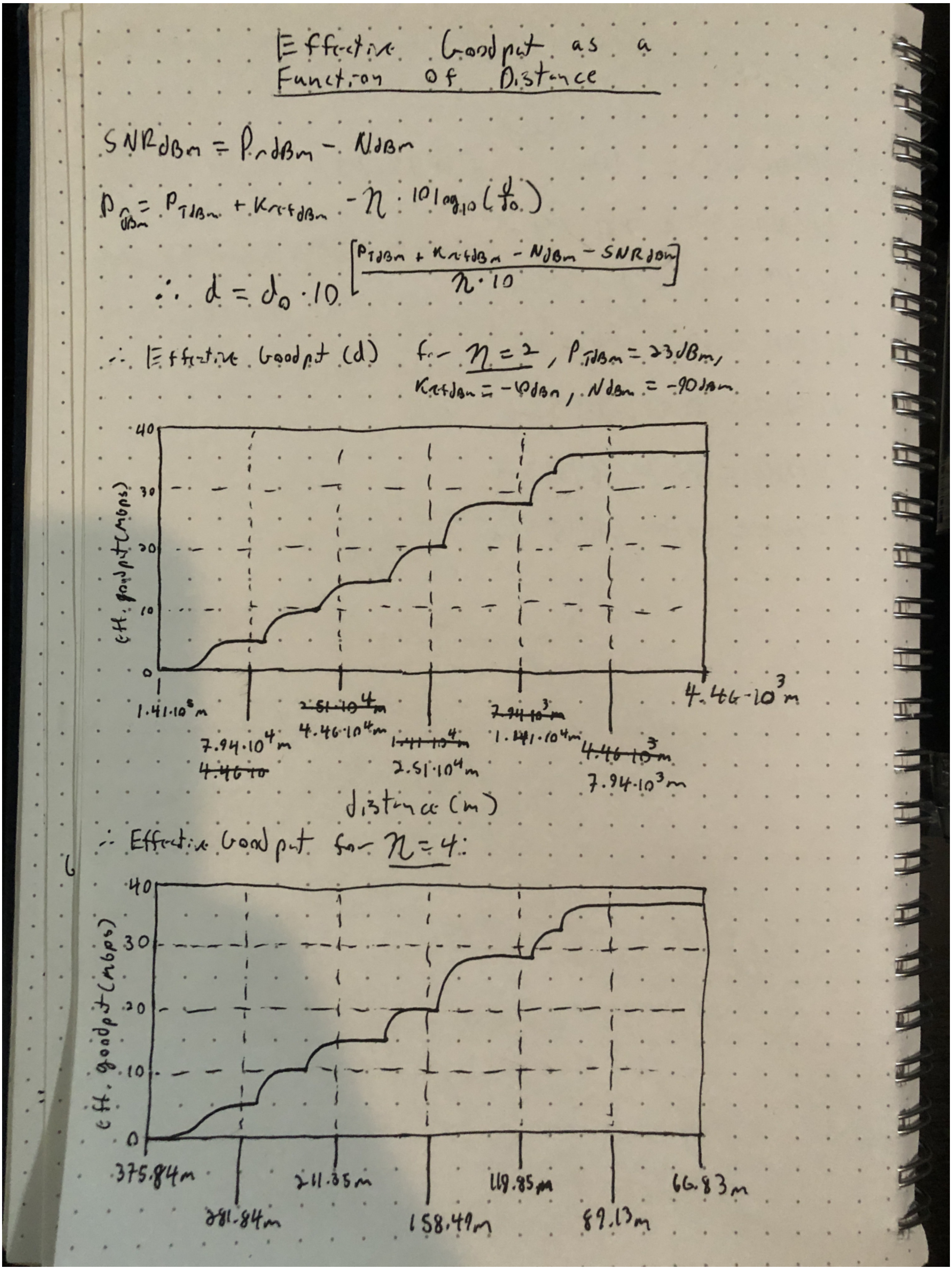
Rate Adaptation





In this exercise, we converted SNR to distance with a known path loss model. P_TdBm = 23dBm, P_{ref} = -10dBm, NdBm = -90dBm. We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with heta values 2 and 4. Here is a breakdown of the SNR --> d(m) conversions for clarity: d = d0 * $10^{(PTdbm + Pref - NdBm - SNRdBm)/(heta * 10)}$

heta = 2:
d(SNR = 0) = 1.41E5m
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d(SNR = 10) = 4.46E4m
d(SNR = 15) = 2.51E4m
d(SNR = 20) = 1.41E4m
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heta = 4:
d(SNR = 0) = 375.84m
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d(SNR = 10) = 211.35m
d(SNR = 15) = 158.49m
d(SNR = 20) = 118.85m
d(SNR = 25) = 89.13m
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Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

p00 - *the probability that we remain in the "outage" state*
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mobile speed = 0:
p00 = 0.0780
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p01 = 0.1420

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In this exercise, we converted SNR to distance with a known path loss model. # ee597-assignment2 Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by

Bill Wang student id: and Spencer McDonough student id:

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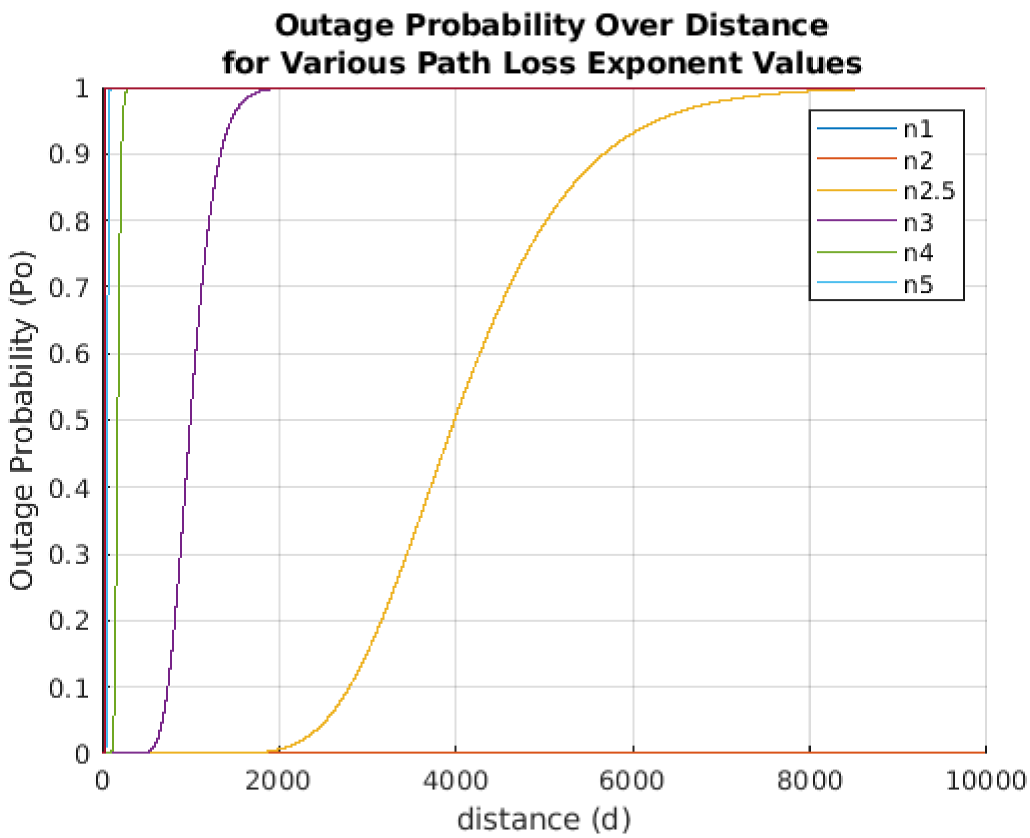

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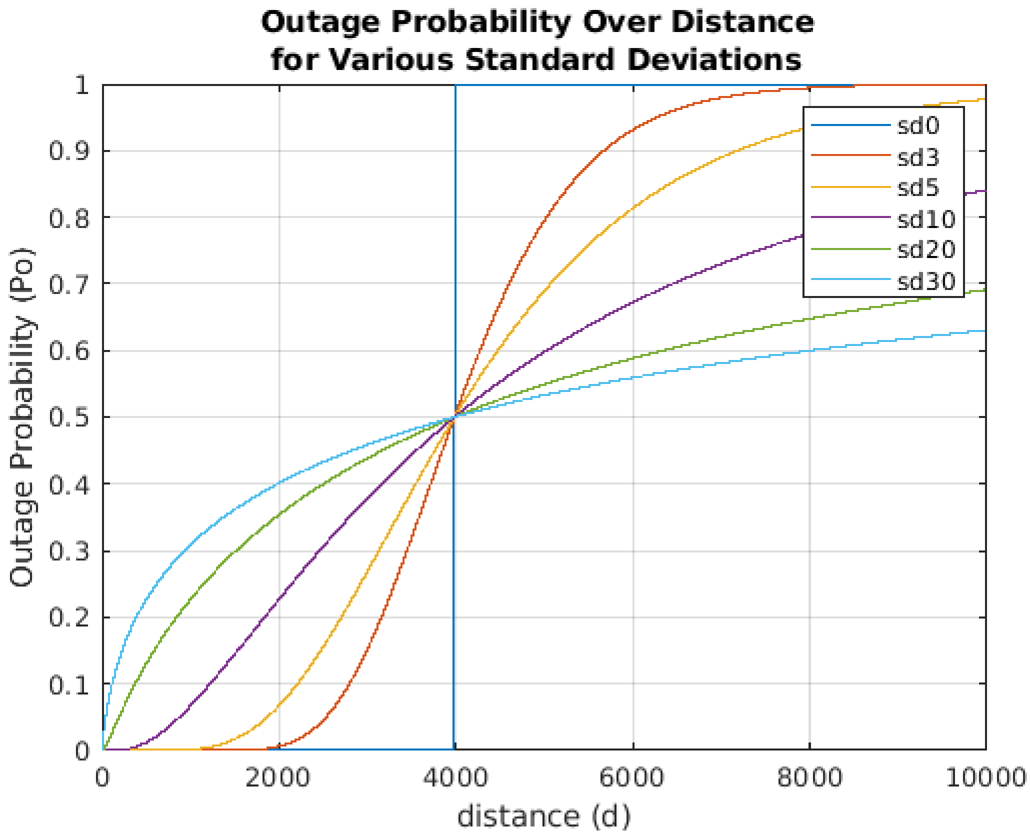

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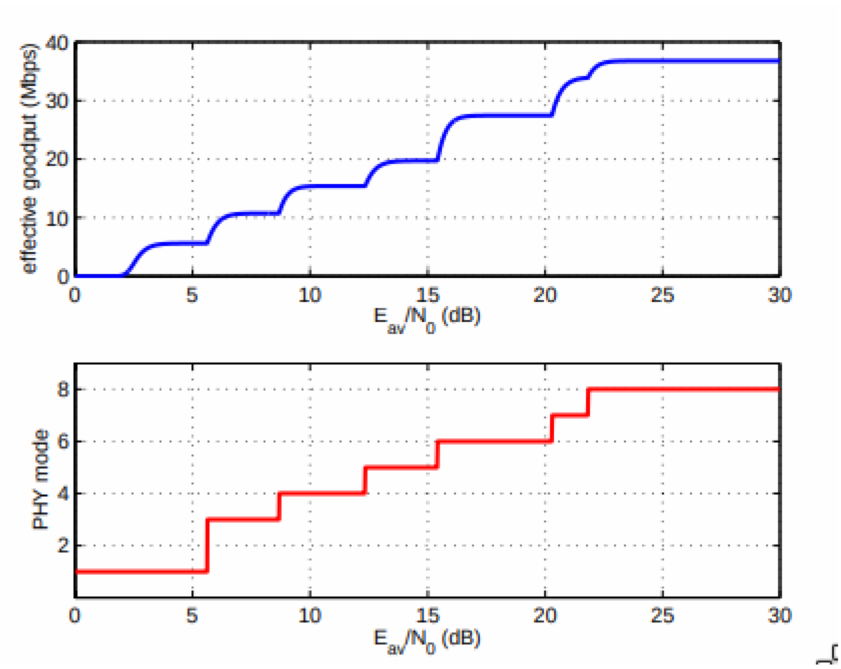
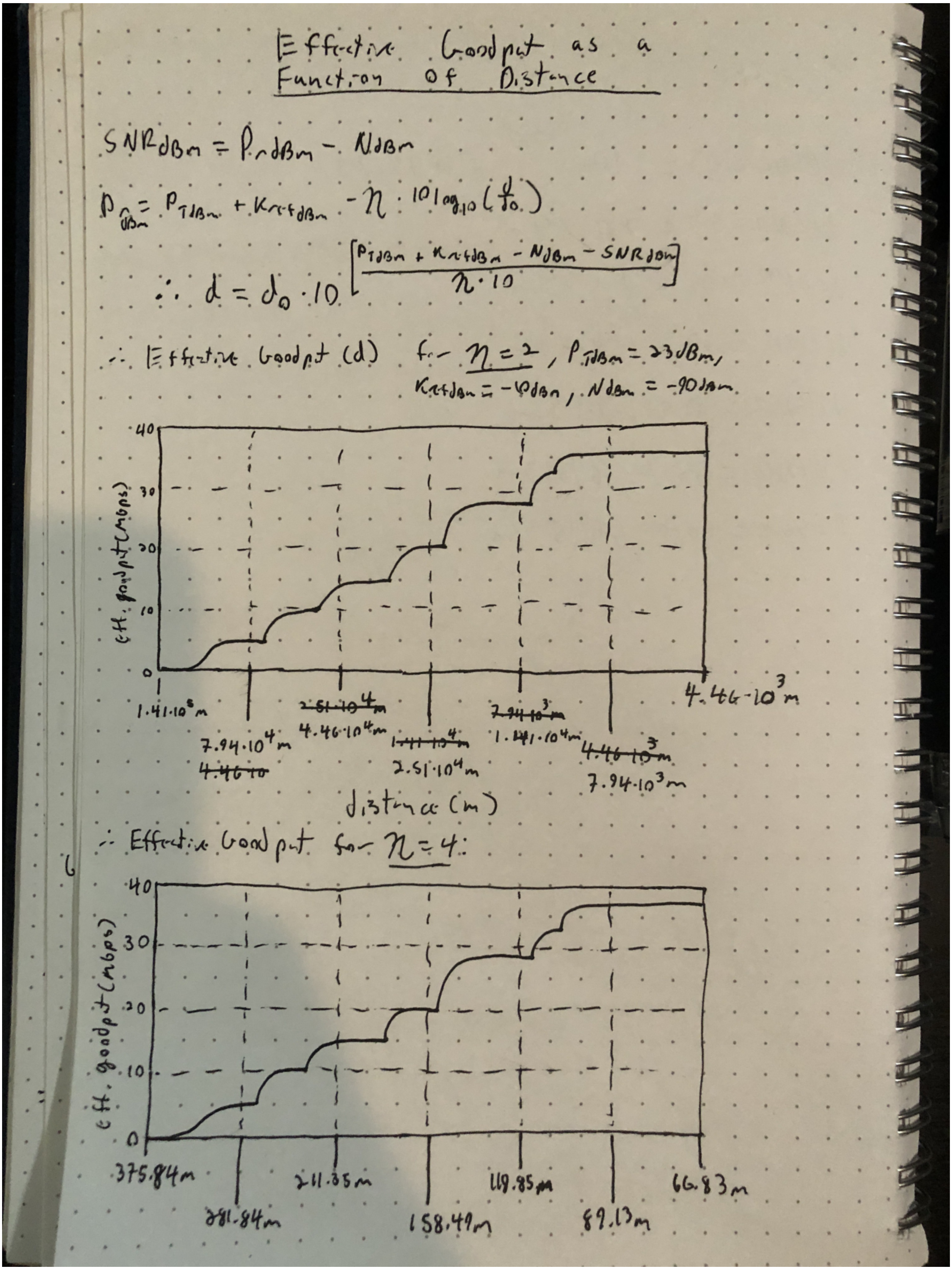
Rate Adaptation





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d(SNR = 20) = 1.41E4m
d(SNR = 25) = 7.94E3m
d(SNR = 30) = 4.46E3m

heta = 4:
d(SNR = 0) = 375.84m
d(SNR = 5) = 281.84m
d(SNR = 10) = 211.35m
d(SNR = 15) = 158.49m
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In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

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p11 - *the probability that we remain in the "receive" state*

mobile speed = 0:
p00 = 0.0780
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mobile speed = 5:
p00 = 0.0775
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by
Bill Wang student id: and Spencer McDonough student id:

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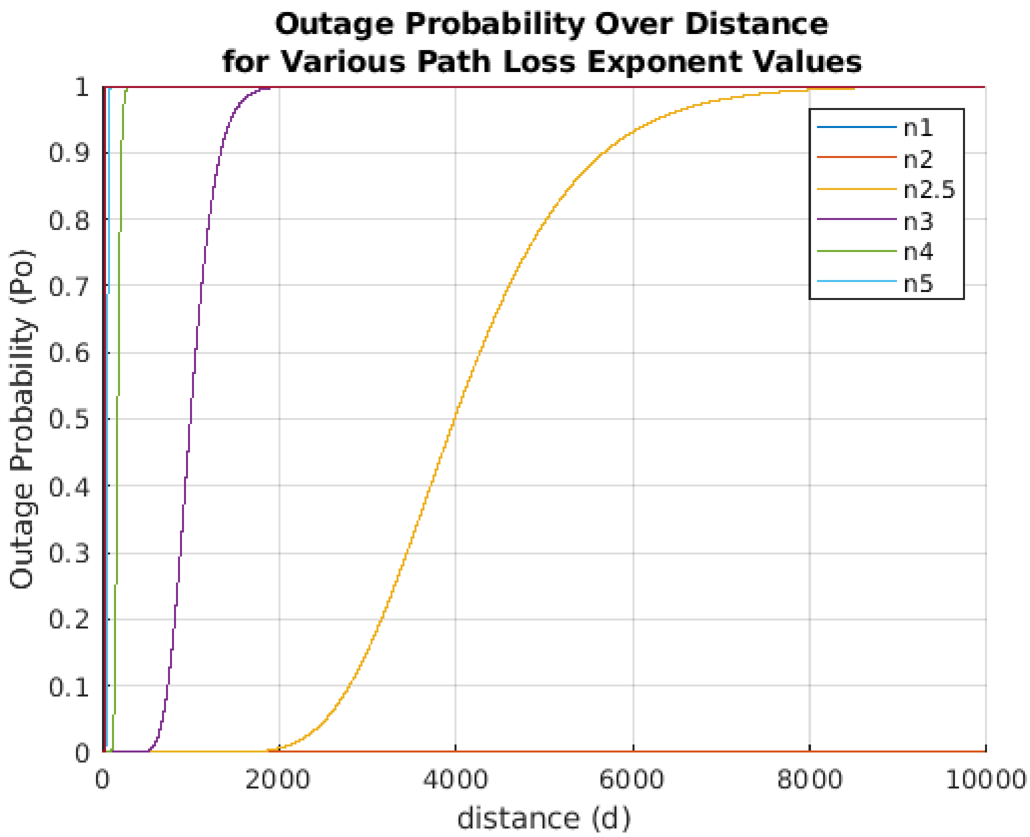

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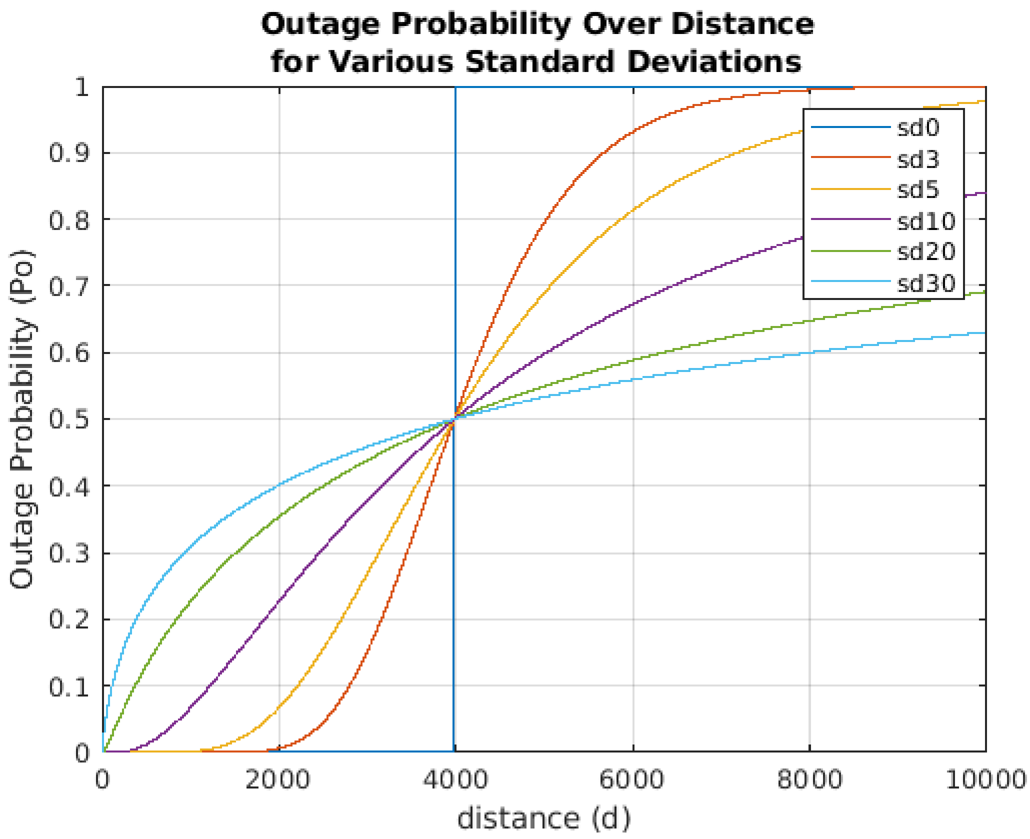

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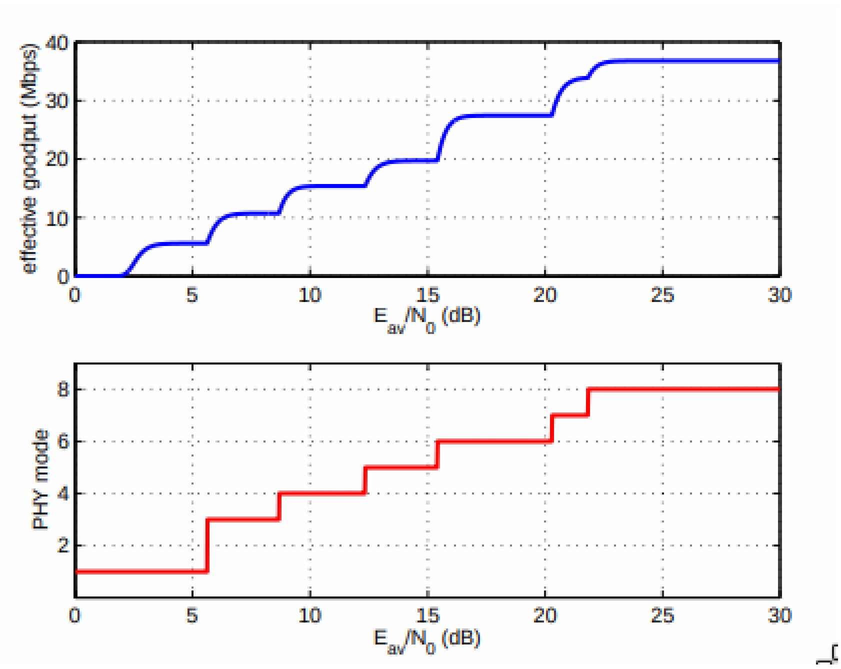
Rate Adaptation



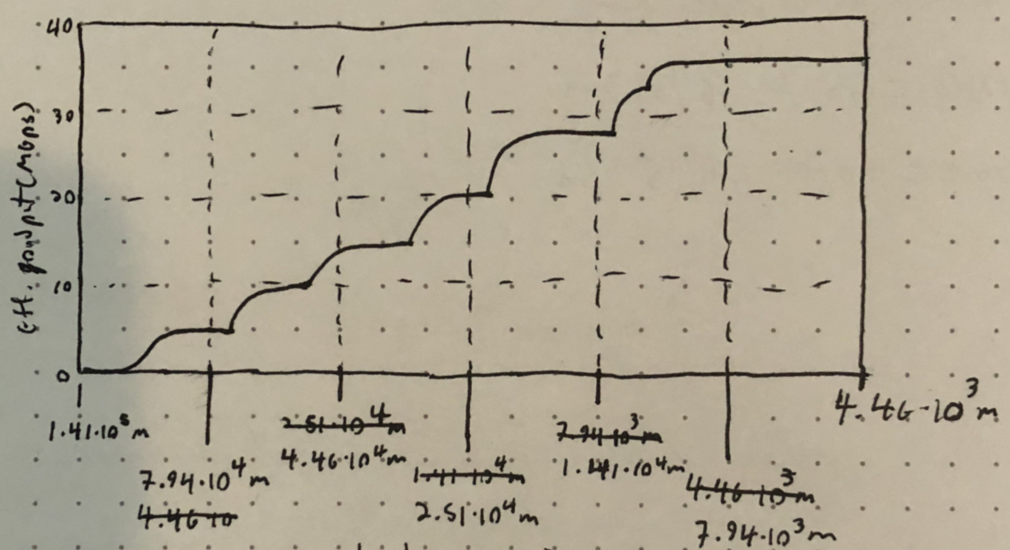
Effective Goodput as a Function of Distance

$SNR_{dBm} = P_{r\,dBm} - N_{dBm}$

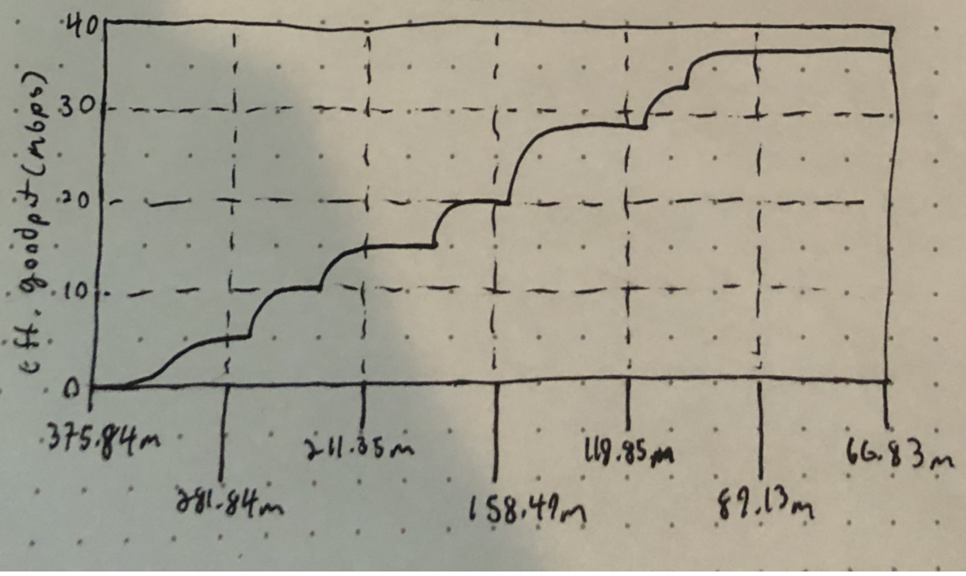
$P_{r\,dBm} = P_{T\,dBm} + K_{ref\,dBm} - \eta \cdot 10\log_{10}\left(\frac{d}{d_0}\right)$

$$\therefore d = d_0 \cdot 10^{\left[\frac{P_{T\,dBm} + K_{ref\,dBm} - N_{dBm} - SNR_{dBm}}{\eta \cdot 10}\right]}$$

∴ Effective Goodput (d) for $\underline{\eta = 2}$, $P_{T\,dBm} = 23dBm$, $K_{ref\,dBm} = -10dBm$, $N_{dBm} = -90dBm$



∴ Effective Goodput for $\underline{\eta = 4}$:



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mobile speed = 0:
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figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance # ee597-assignment2 Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by

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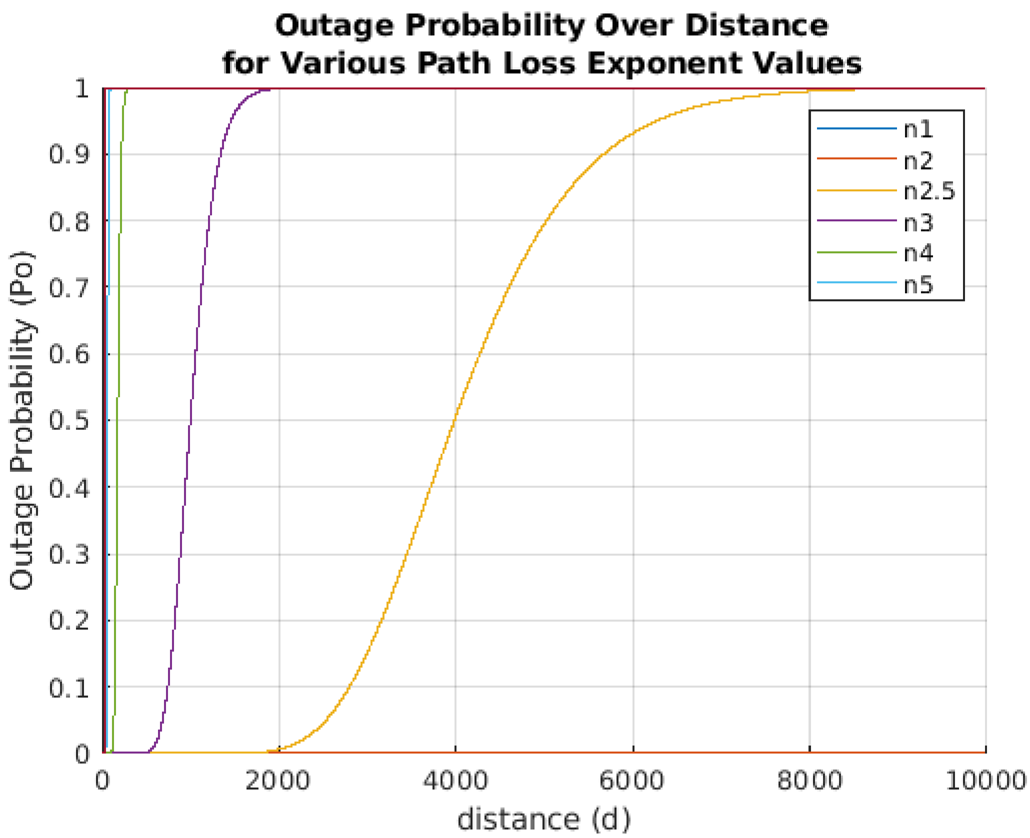

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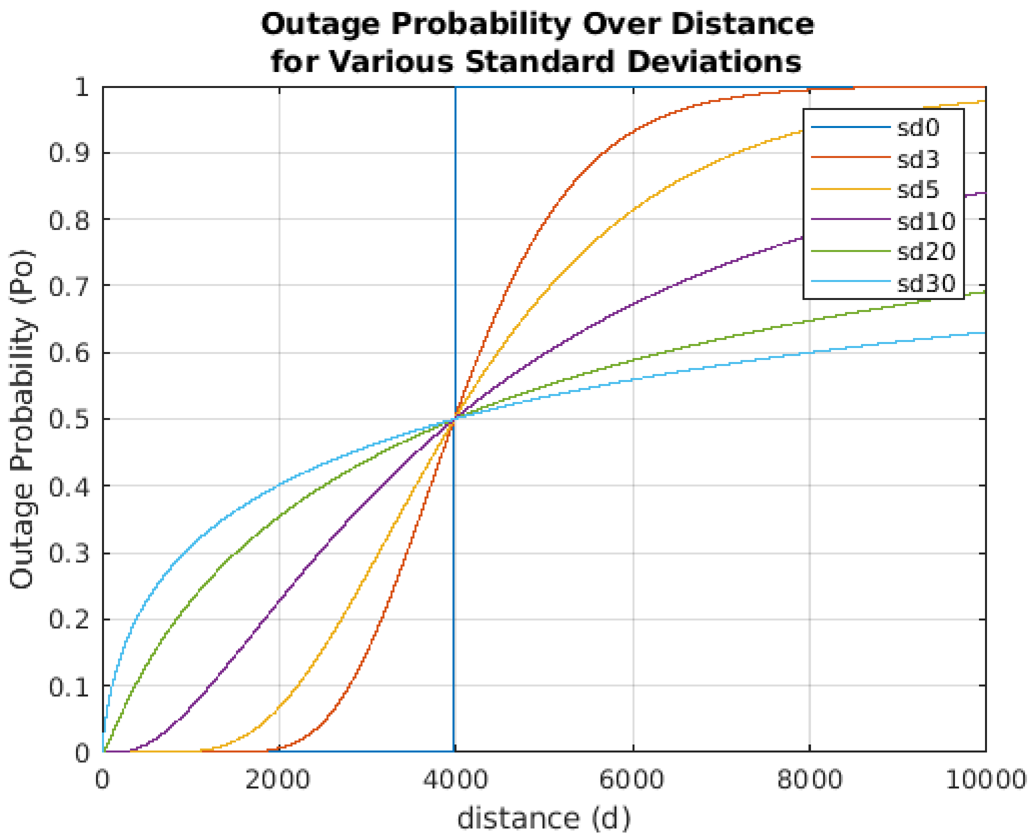

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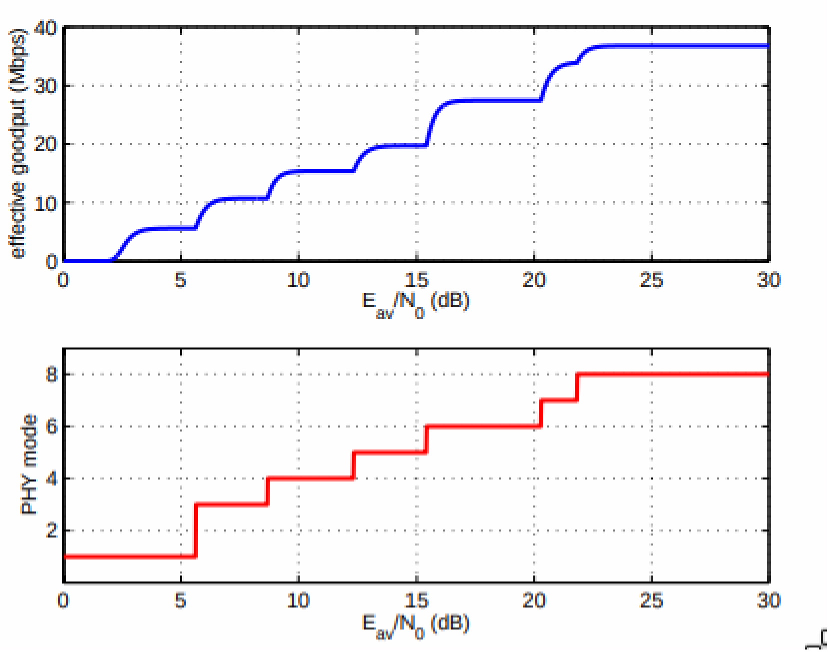
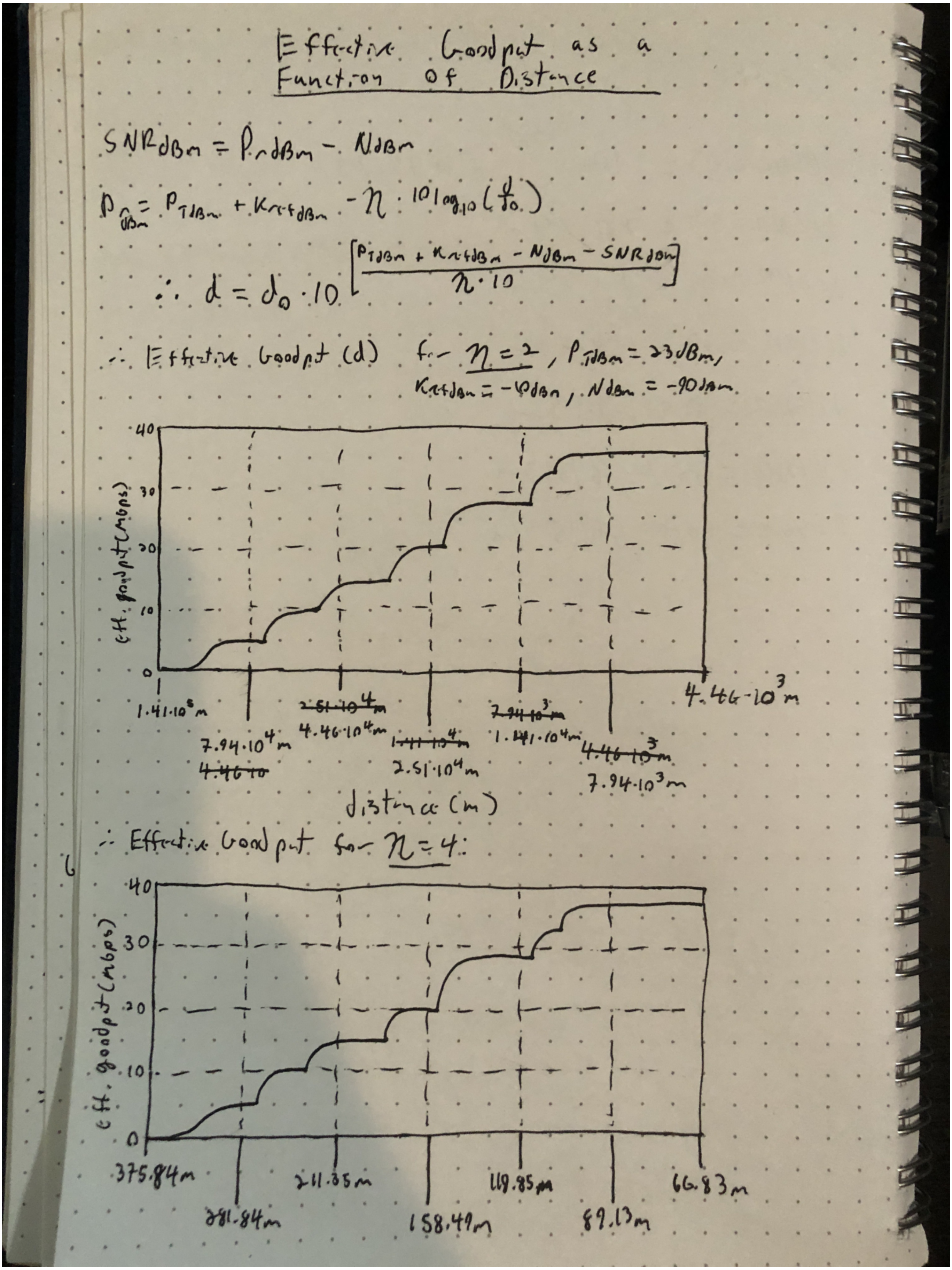
Rate Adaptation





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d(SNR = 30) = 4.46E3m

heta = 4:
d(SNR = 0) = 375.84m
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p11 - *the probability that we remain in the "receive" state*

mobile speed = 0:
p00 = 0.0780
p01 = 0.1400
p10 = 0.1395
p11 = 0.6420

mobile speed = 5:
p00 = 0.0775
p01 = 0.1490
p10 = 0.1490
p11 = 0.6240

mobile speed = 10:
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ee597-assignment2

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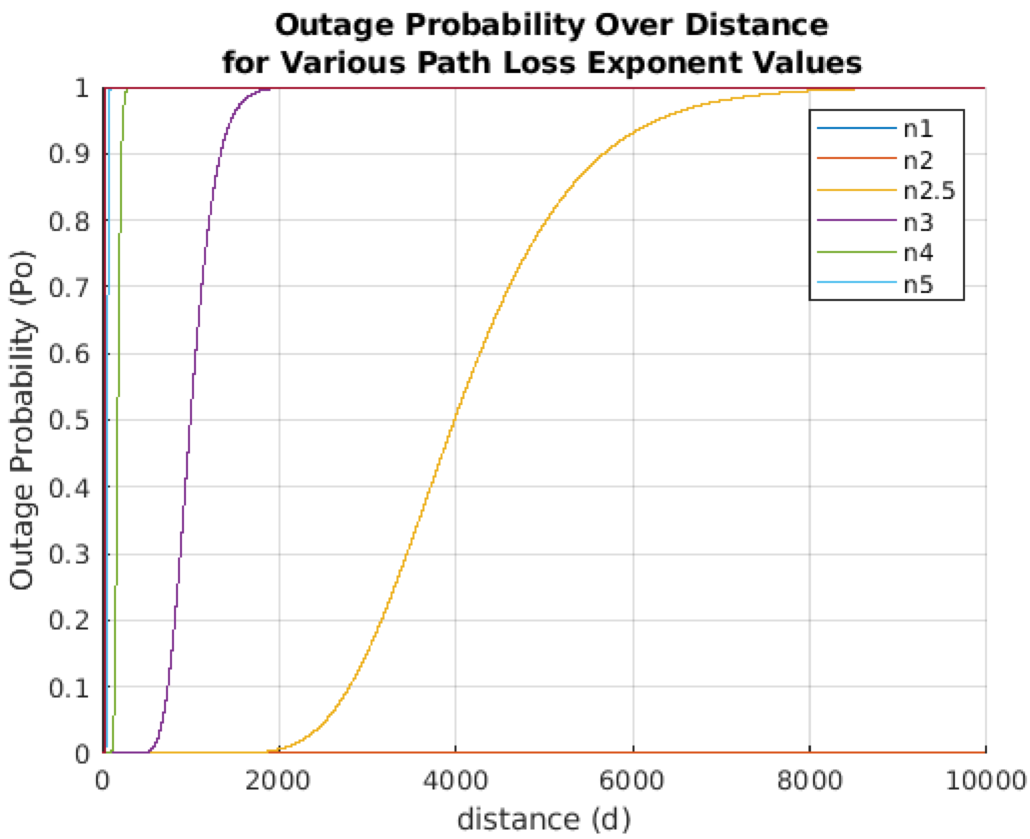

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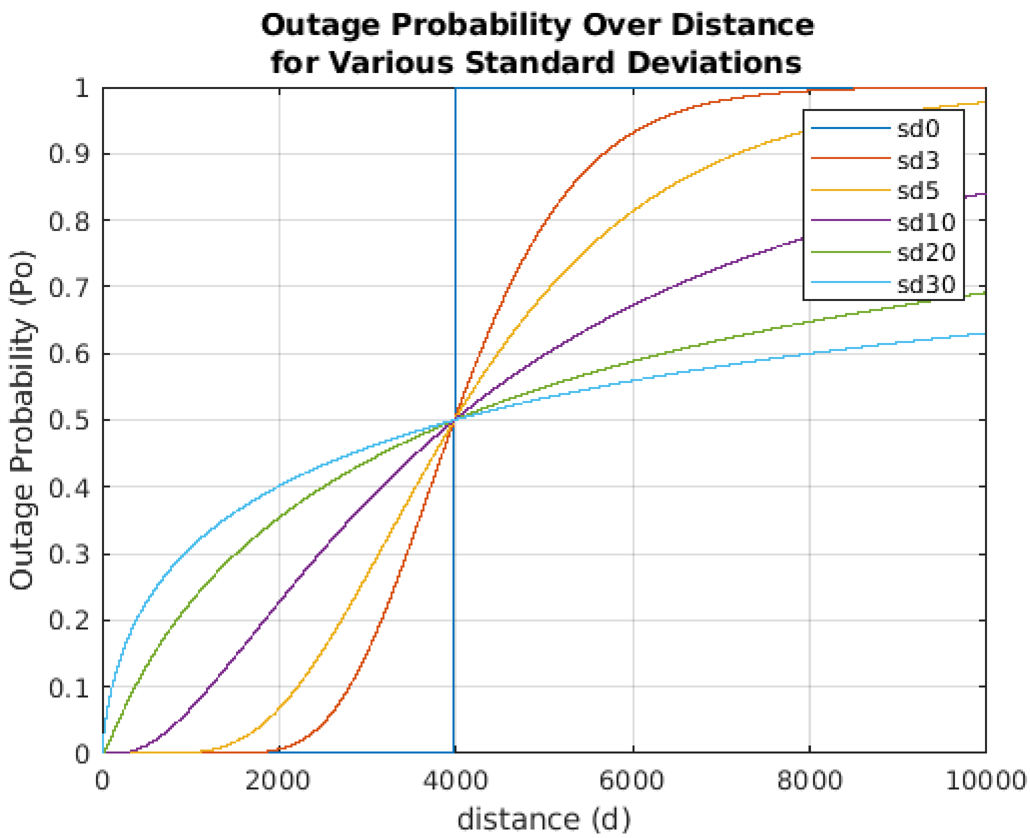

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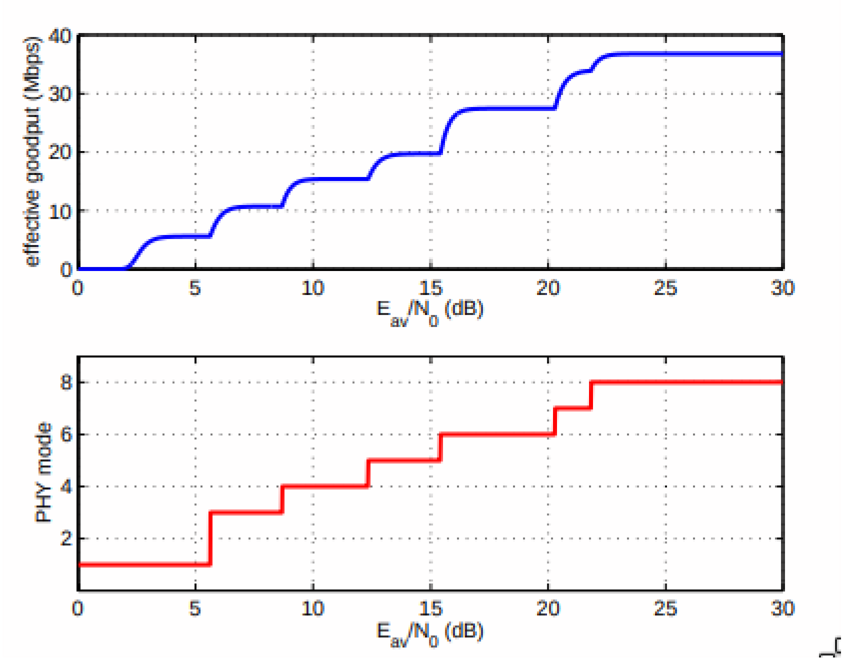

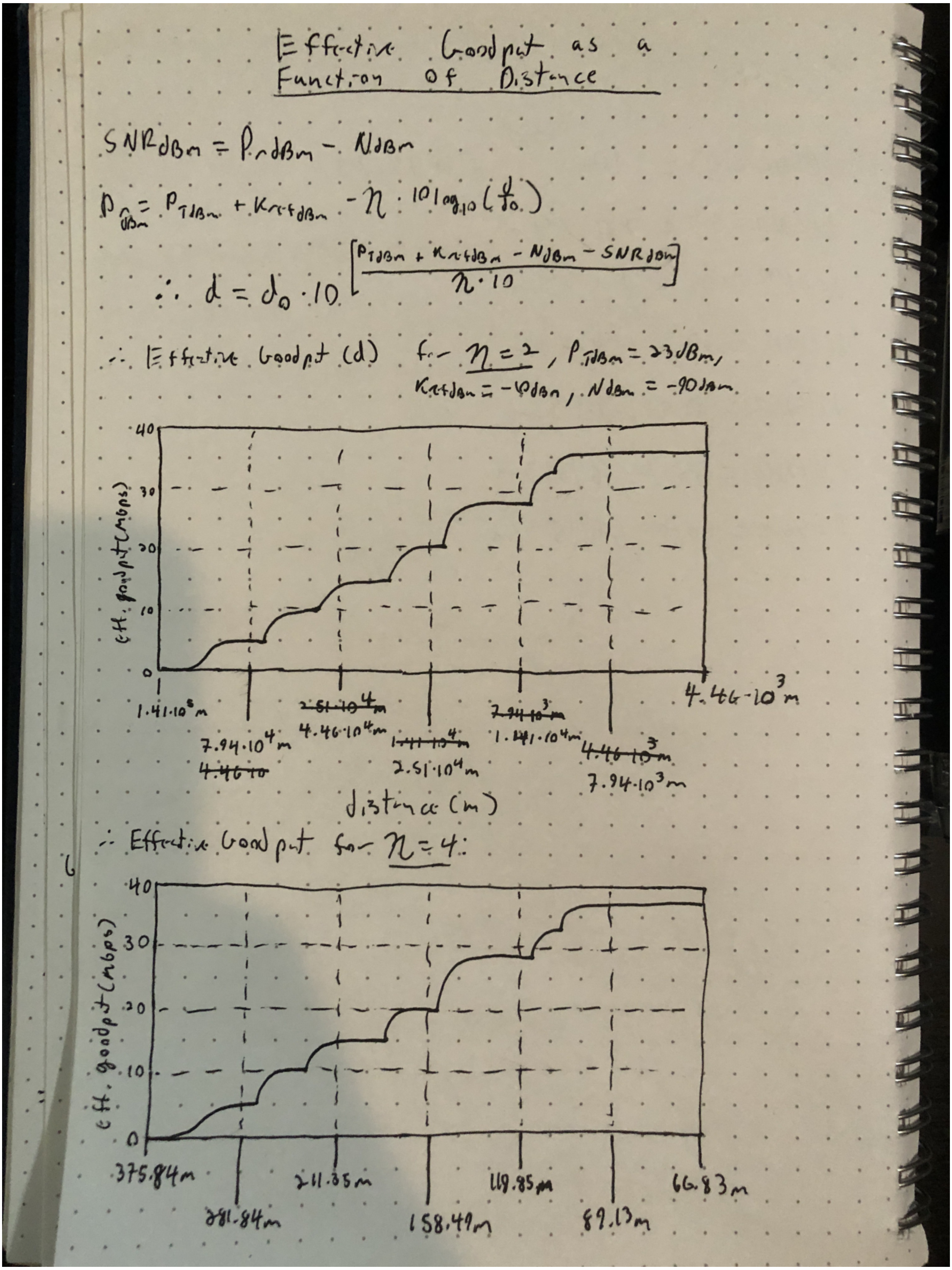

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p10 - *the probability that we move from the "receive" state to the "outage" state*
p11 - *the probability that we remain in the "receive" state*

mobile speed = 0:
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mobile speed = 5:
p00 = 0.0775
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ee597-assignment2

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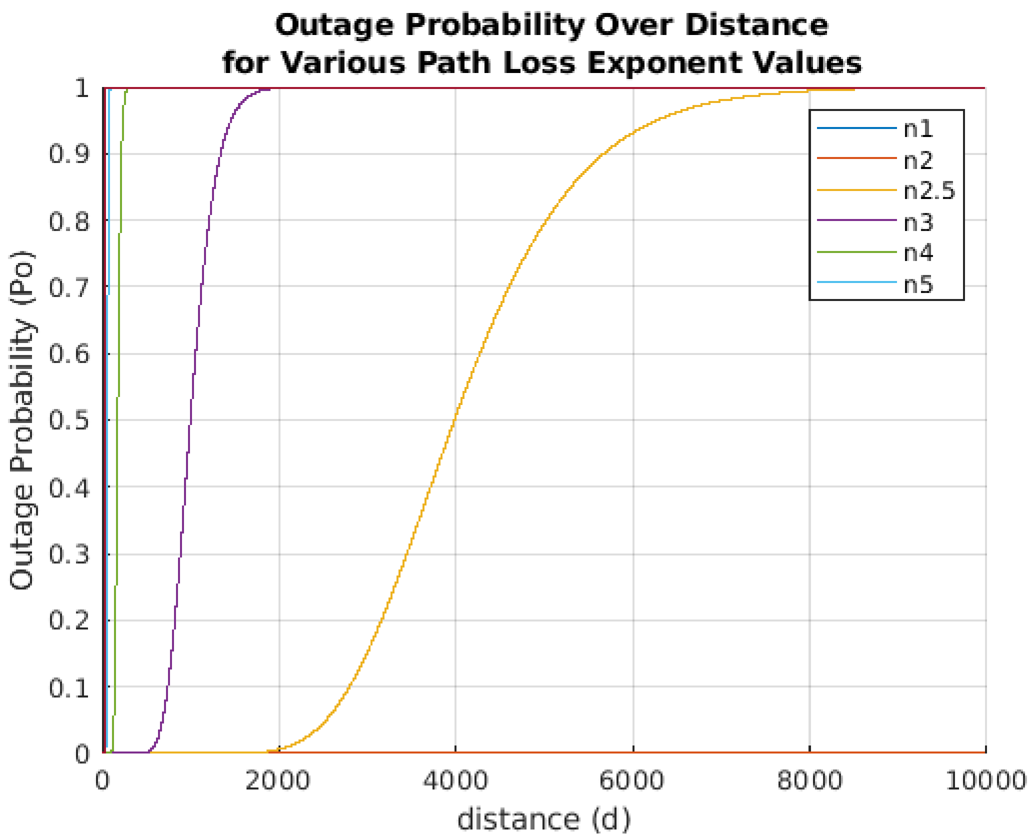

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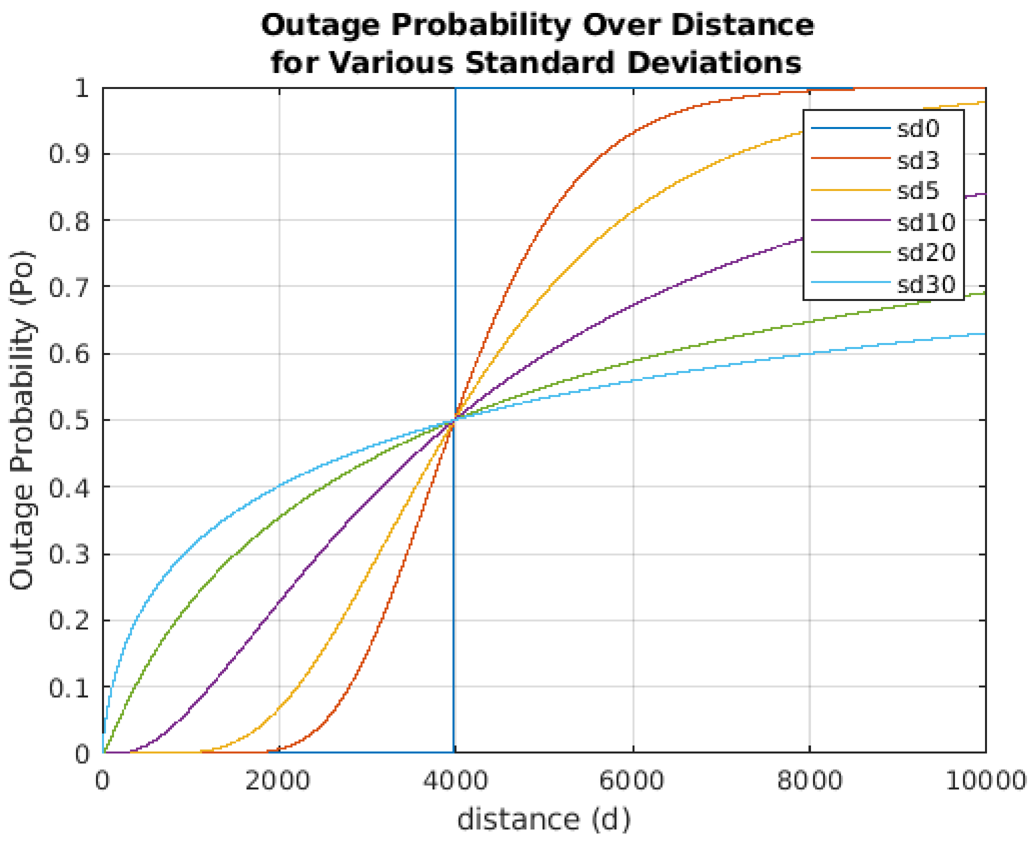

We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponenent (PLE) increases. This makes sense, as the probability of outage is inversely

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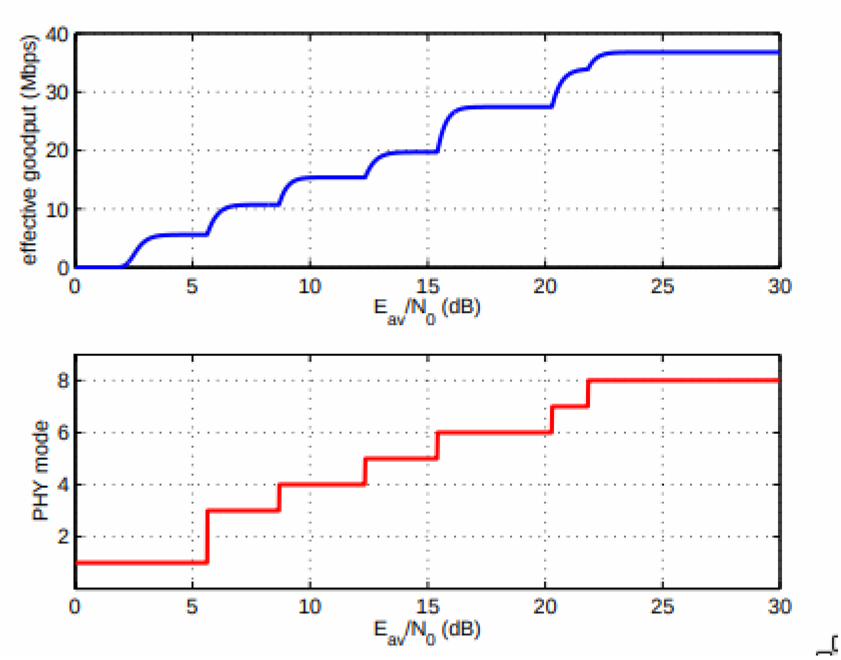
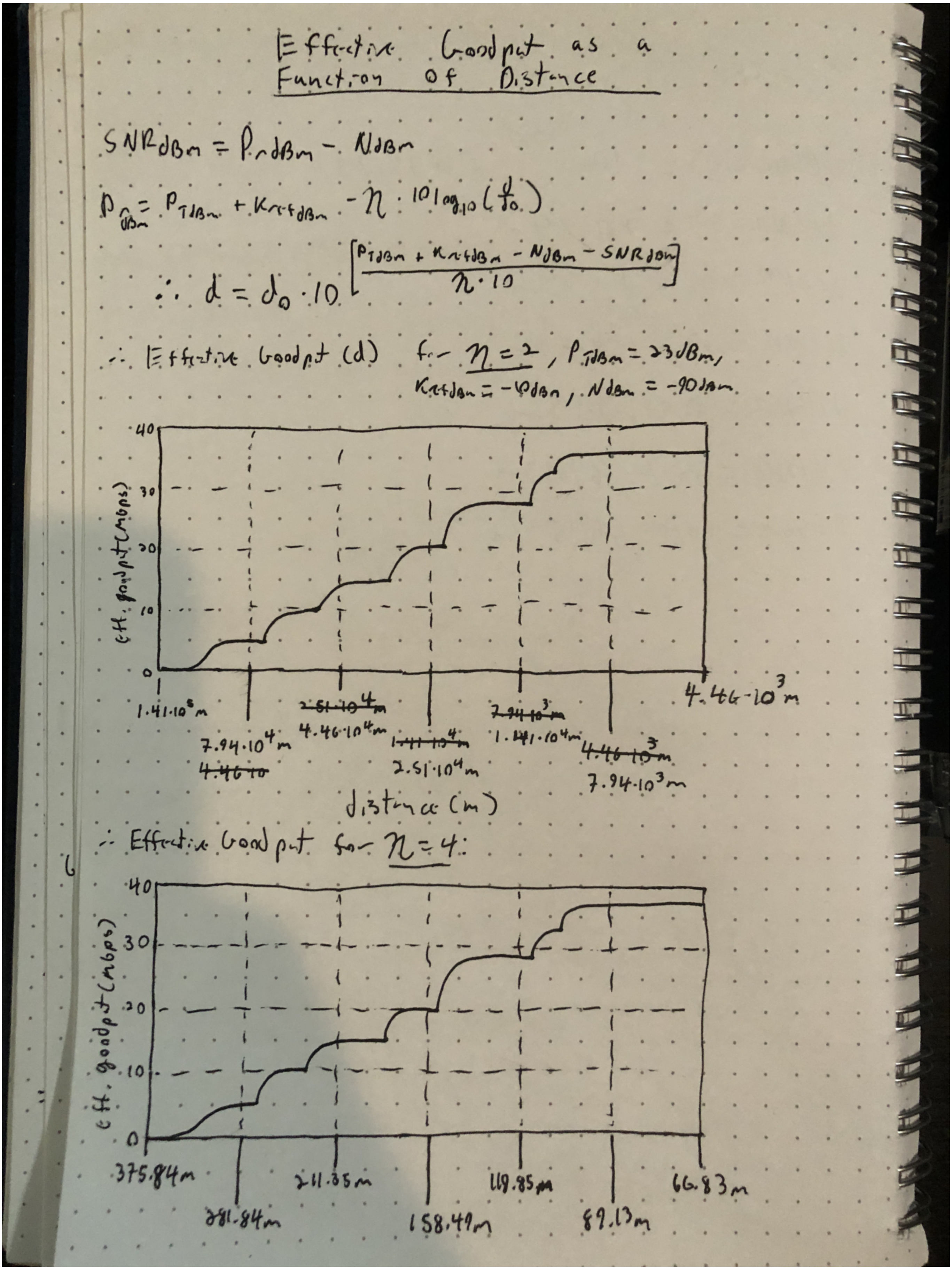
Rate Adaptation





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heta = 2:
d(SNR = 0) = 1.41E5m
d(SNR = 5) = 7.94E4m
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d(SNR = 15) = 2.51E4m
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d(SNR = 25) = 7.94E3m
d(SNR = 30) = 4.46E3m

heta = 4:
d(SNR = 0) = 375.84m
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Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

p00 - *the probability that we remain in the "outage" state*
p01 - *the probability that we move from the "outage" state to the "receive" state*
p10 - *the probability that we move from the "receive" state to the "outage" state*
p11 - *the probability that we remain in the "receive" state*

mobile speed = 0:
p00 = 0.0780
p01 = 0.1400
p10 = 0.1395
p11 = 0.6420

mobile speed = 5:
p00 = 0.0775
p01 = 0.1490
p10 = 0.1490
p11 = 0.6240

mobile speed = 10:
p00 = 0.0715
p01 = 0.1430
p10 = 0.1425
p11 = 0.6425

mobile speed = 15:
p00 = 0.0655
p01 = 0.1570
p10 = 0.1575
p11 = 0.6195

mobile speed = 20:
p00 = 0.0750
p01 = 0.1420
p10 = 0.1420
p11 = 0.6405

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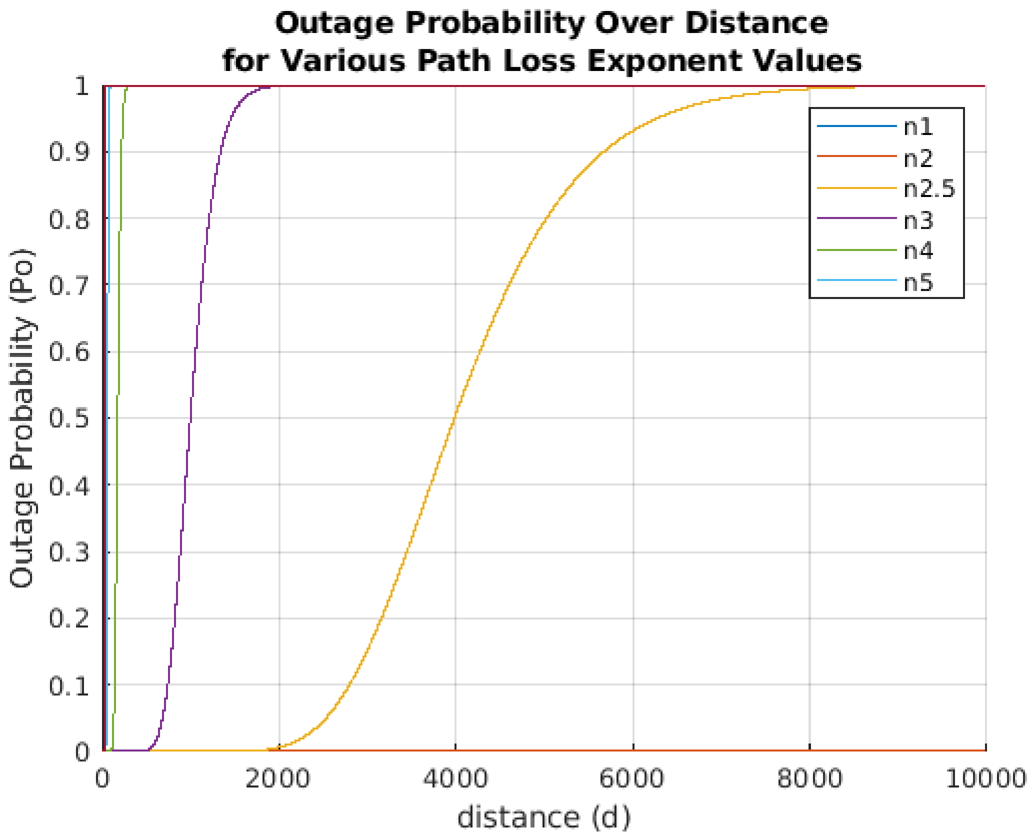
d = d0 * $10^{(PTdbm + Pref - NdBm - SNRdBm)/(heta * 10)}$

ee597-assignment2

Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by
Bill Wang student id: and Spencer McDonough student id:

Outage Probability as a function of distance for Log-Normal Shadowing



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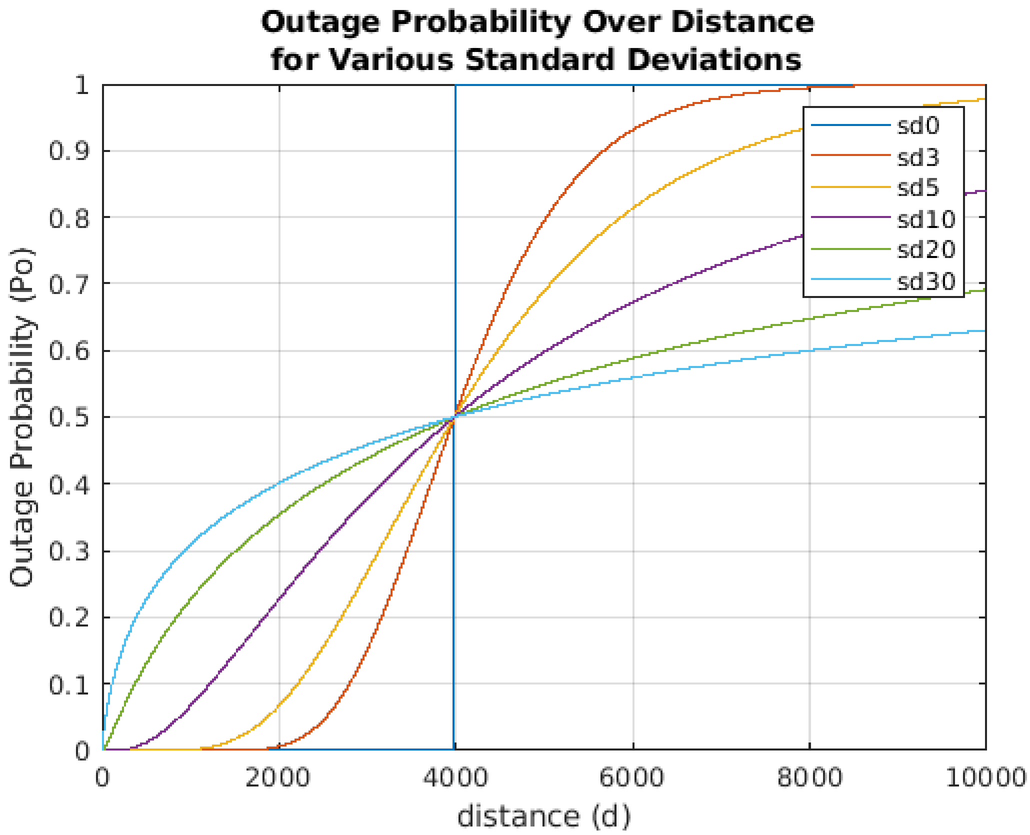

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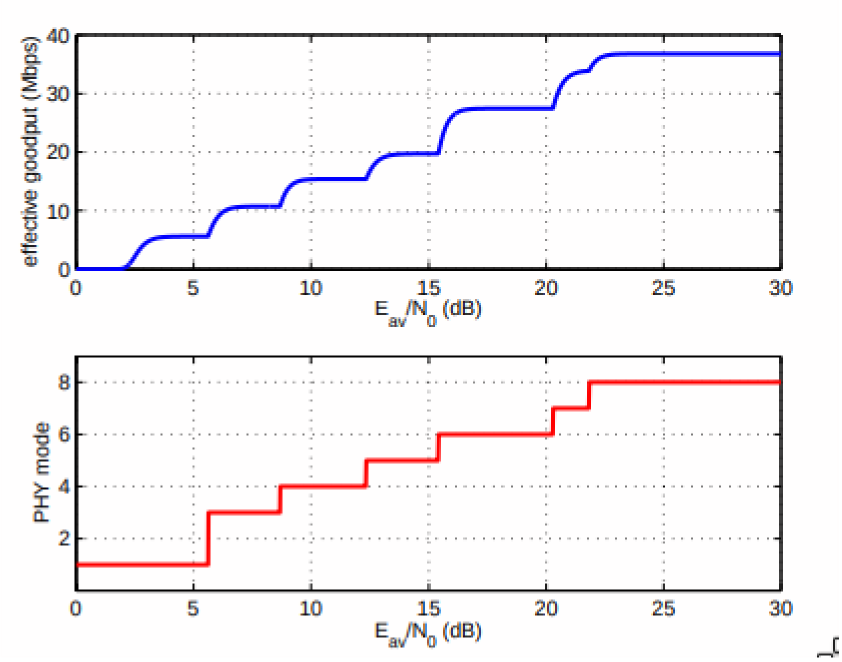
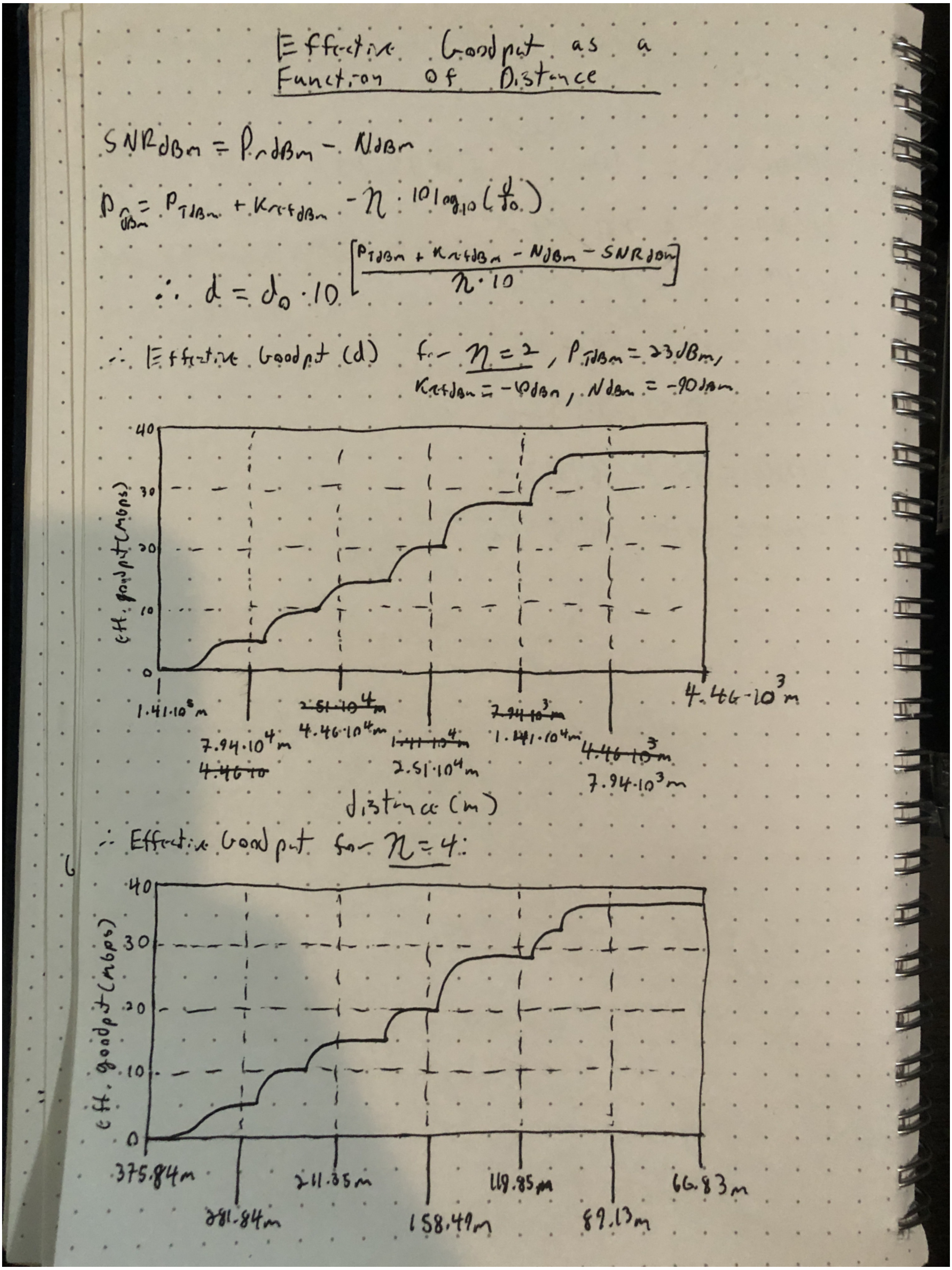
Rate Adaptation





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mobile speed = 0:
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ee597-assignment2

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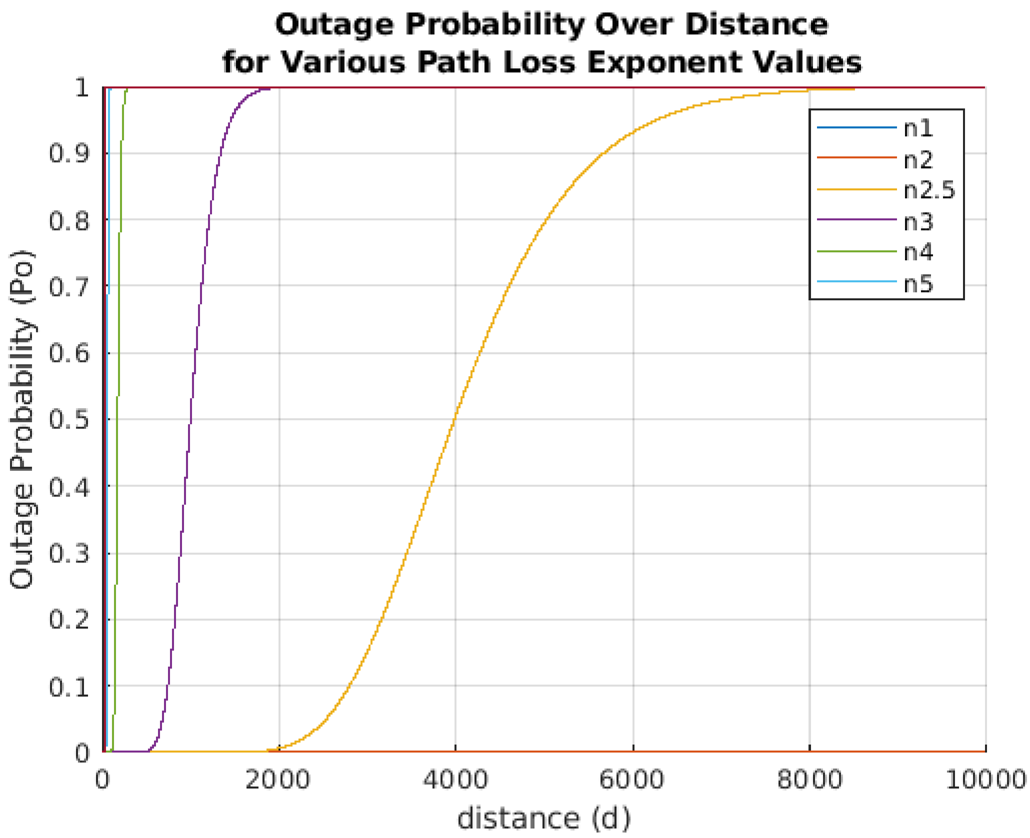

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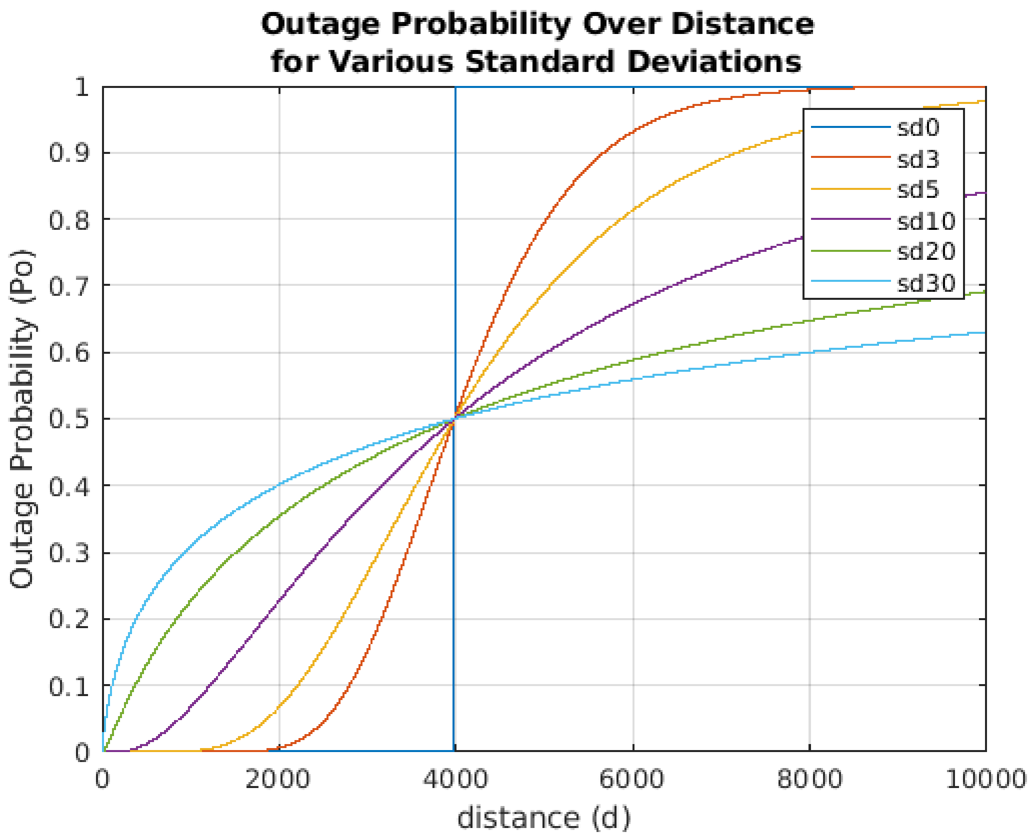

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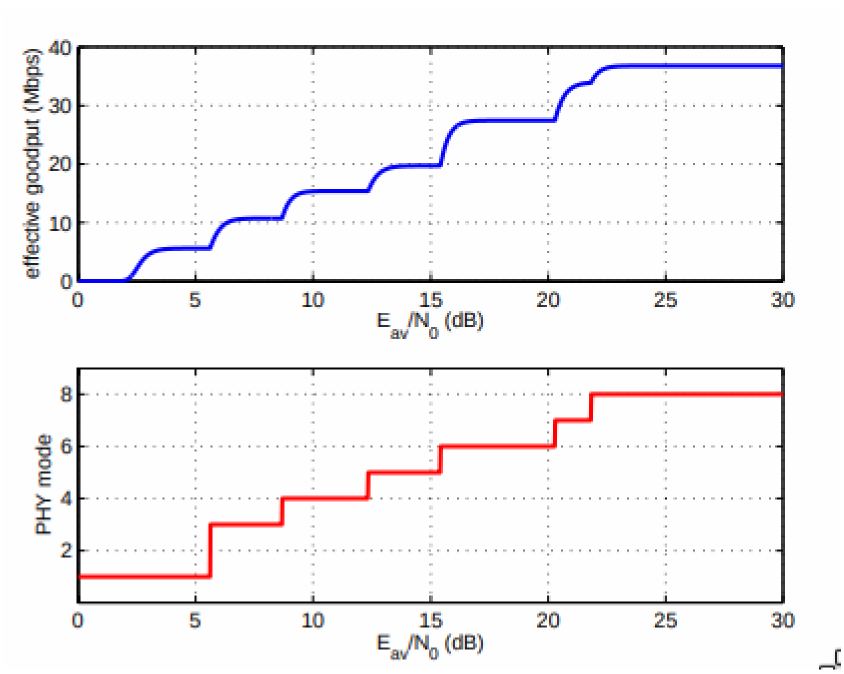

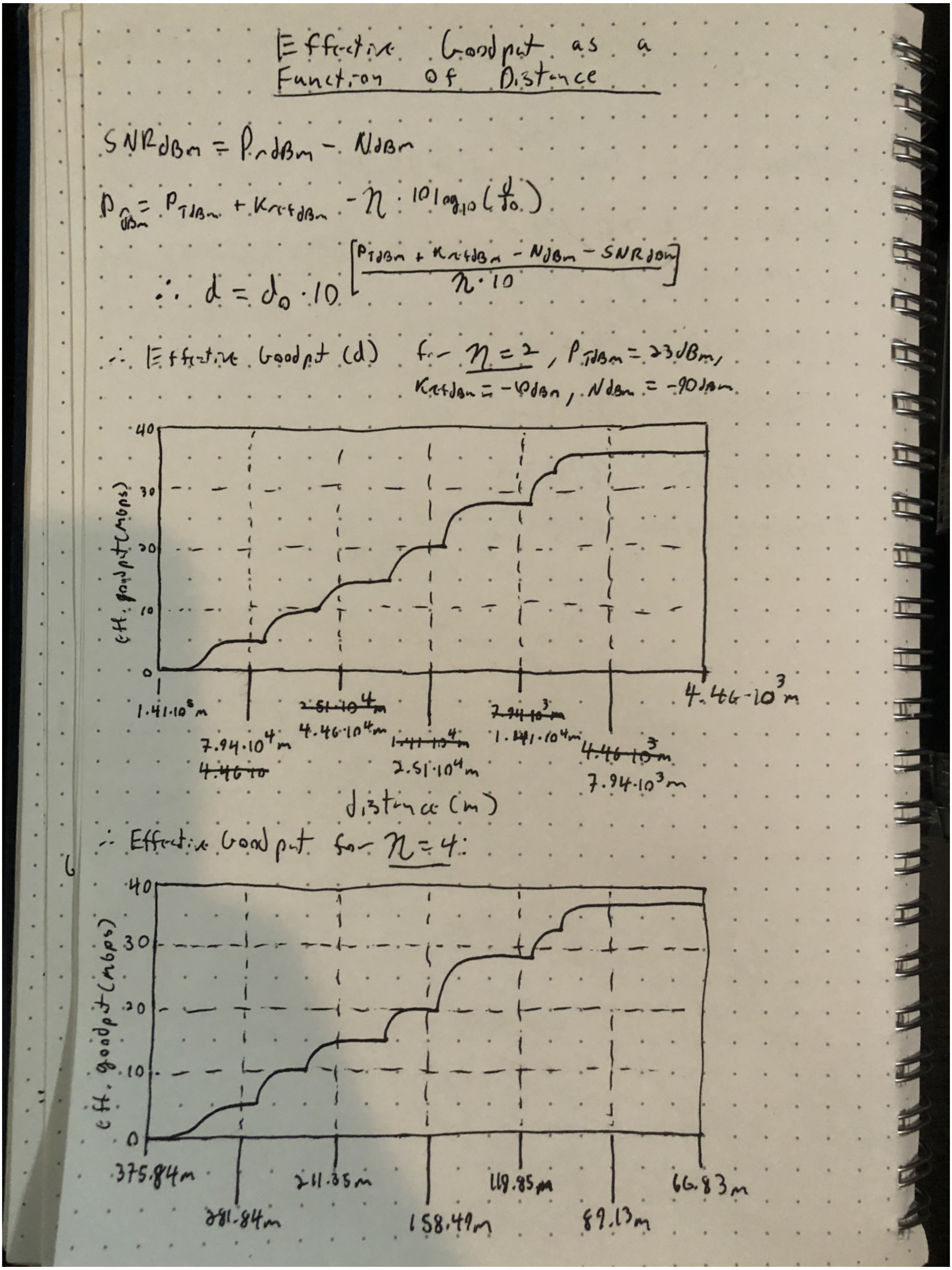

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p11 = 0.6420

mobile speed = 5:
p00 = 0.0775
p01 = 0.1490
p10 = 0.1490
p11 = 0.6240

mobile speed = 10:
p00 = 0.0715
p01 = 0.1430
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p10 = 0.1485
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heta = 2:

ee597-assignment2

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by
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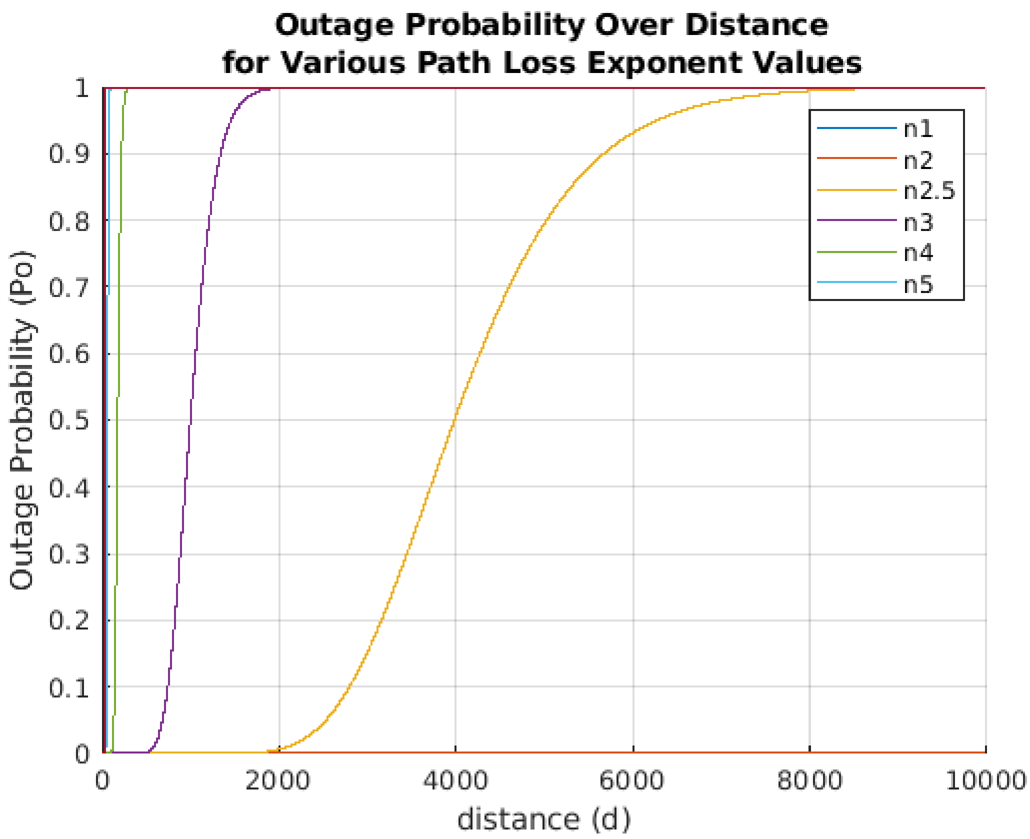

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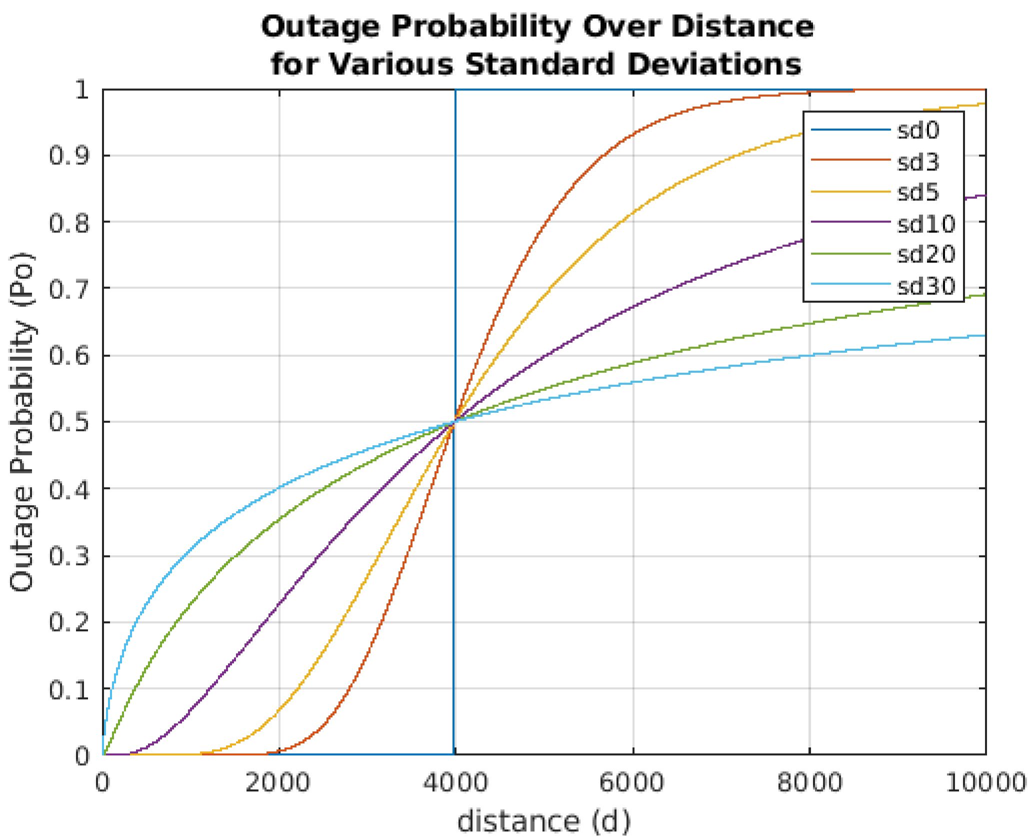

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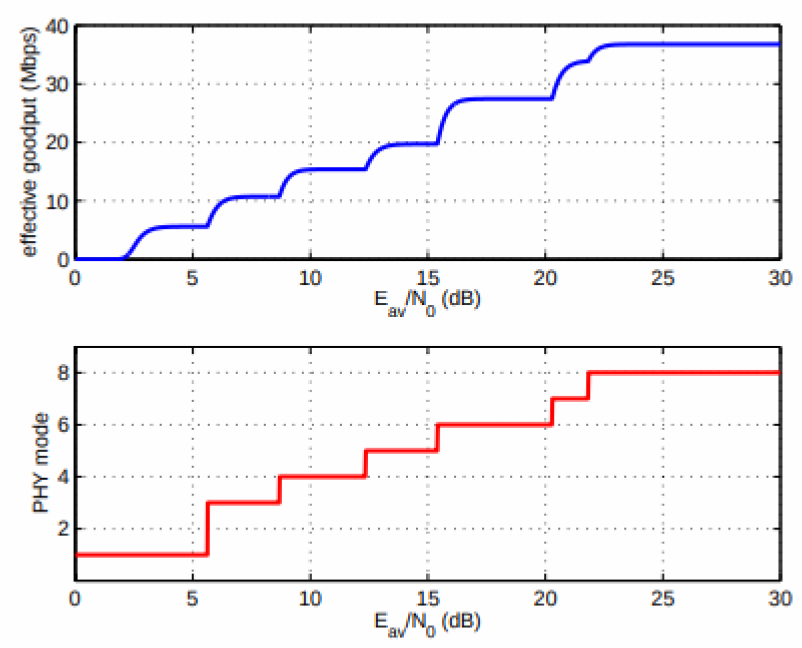

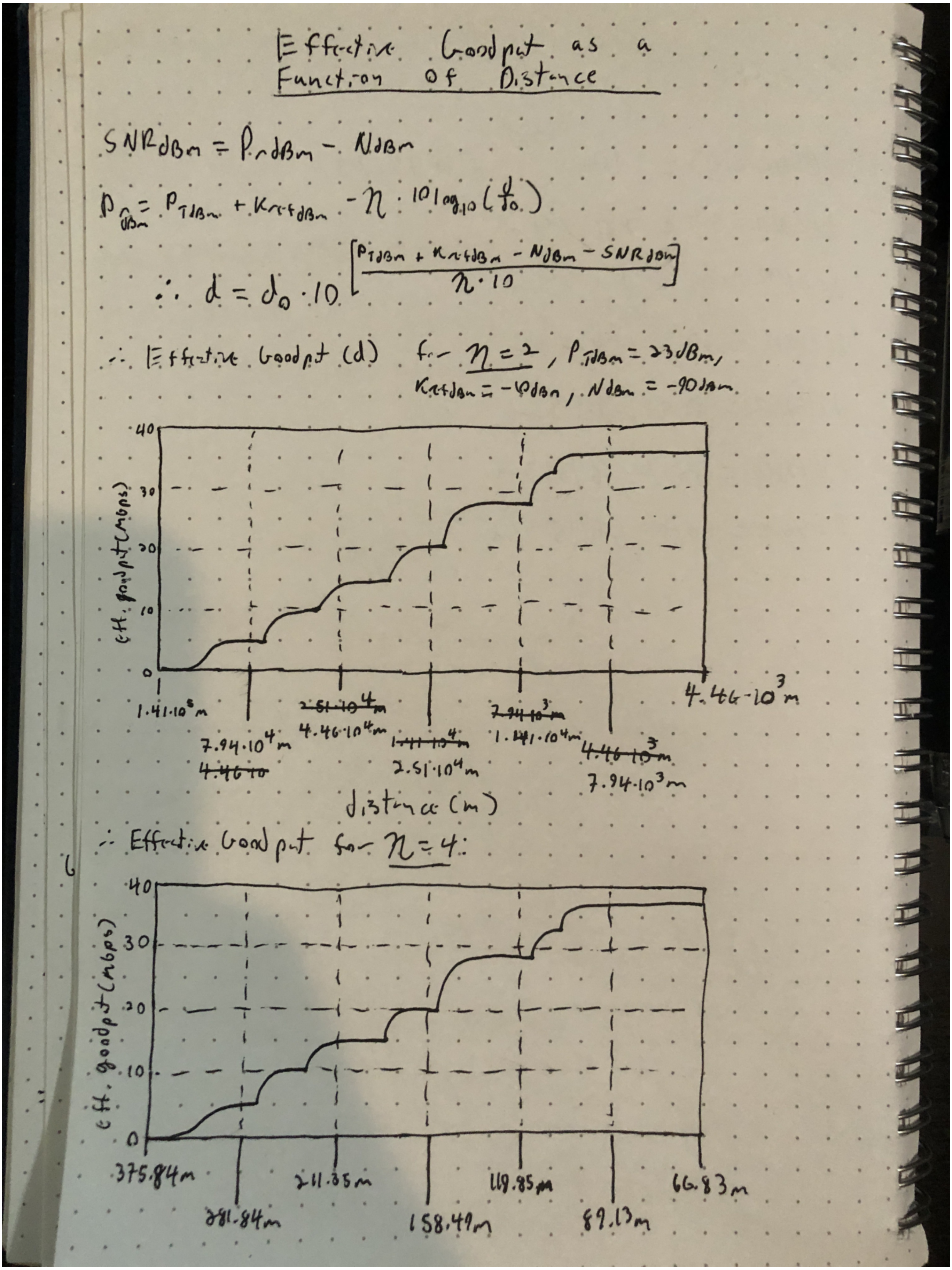

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heta = 4:
d(SNR = 0) = 375.84m
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p11 - *the probability that we remain in the "receive" state*

mobile speed = 0:
p00 = 0.0780
p01 = 0.1400
p10 = 0.1395
p11 = 0.6420

mobile speed = 5:
p00 = 0.0775
p01 = 0.1490
p10 = 0.1490
p11 = 0.6240

mobile speed = 10:
p00 = 0.0715
p01 = 0.1430
p10 = 0.1425
p11 = 0.6425

mobile speed = 15:
p00 = 0.0655
p01 = 0.1570
p10 = 0.1575
p11 = 0.6195

mobile speed = 20:
p00 = 0.0750
p01 = 0.1420
p10 = 0.1420
p11 = 0.6405

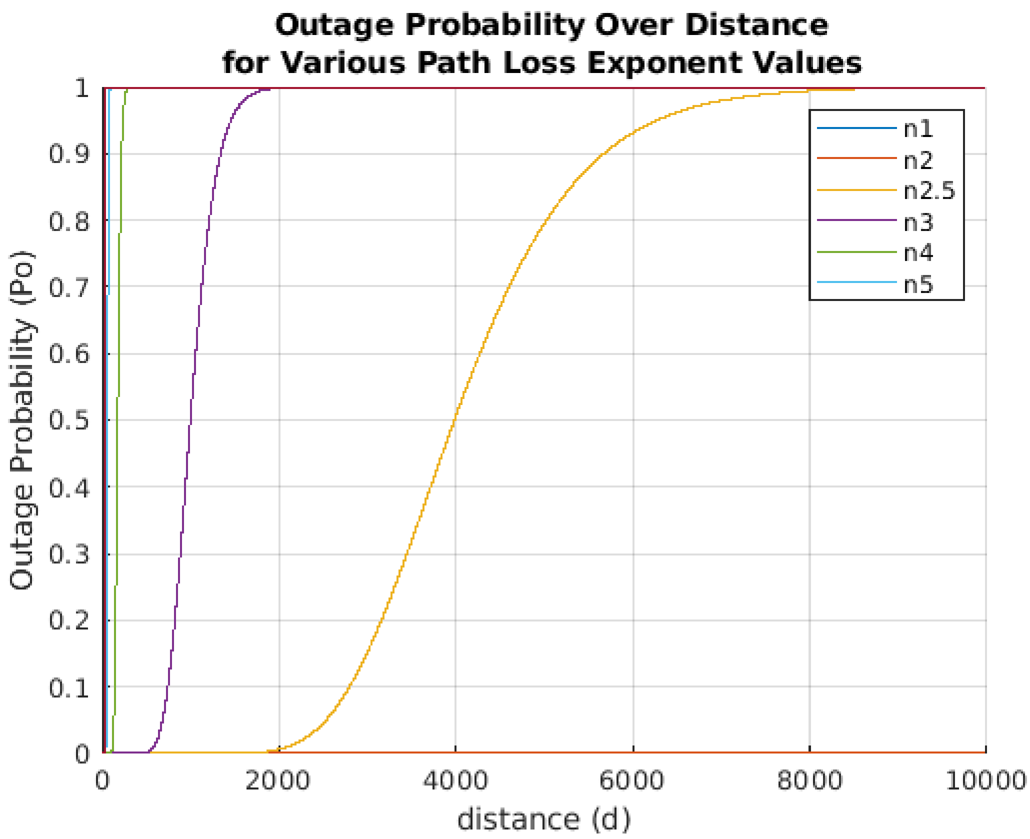
mobile speed = 25:
p00 = 0.0810
p01 = 0.1485
p10 = 0.1485
p11 = 0.6215
d(SNR = 0) = 1.41E5m

ee597-assignment2

Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by
Bill Wang student id: and Spencer McDonough student id:

Outage Probability as a function of distance for Log-Normal Shadowing



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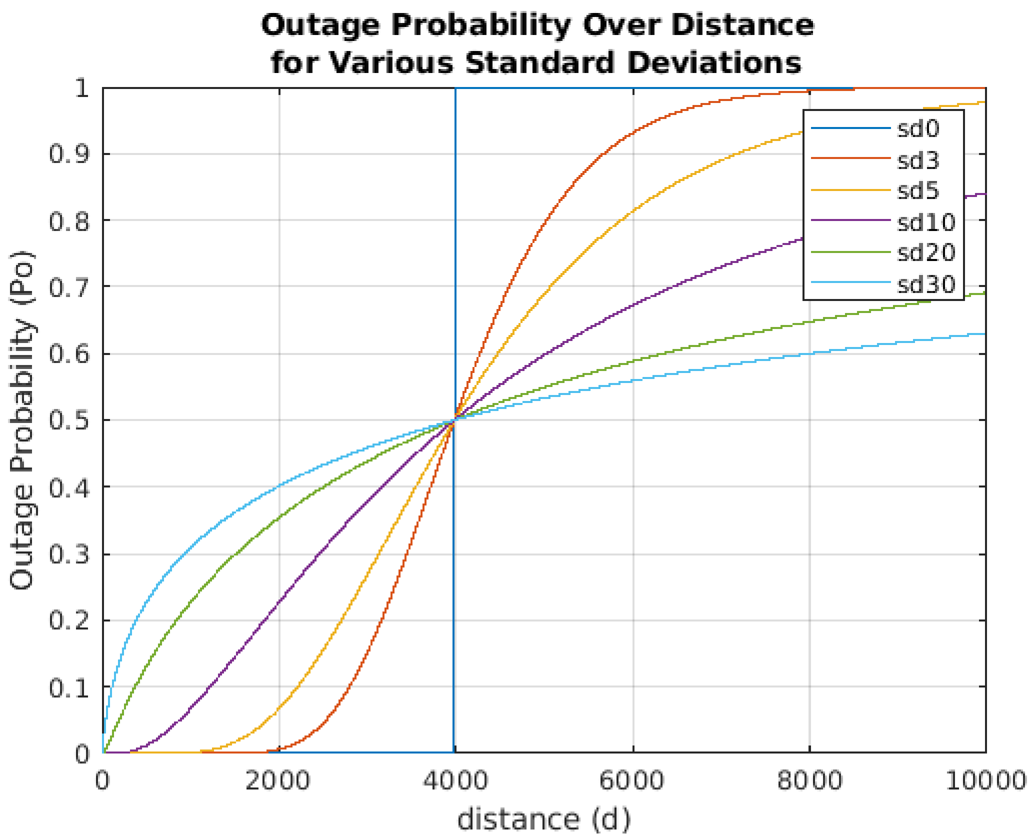

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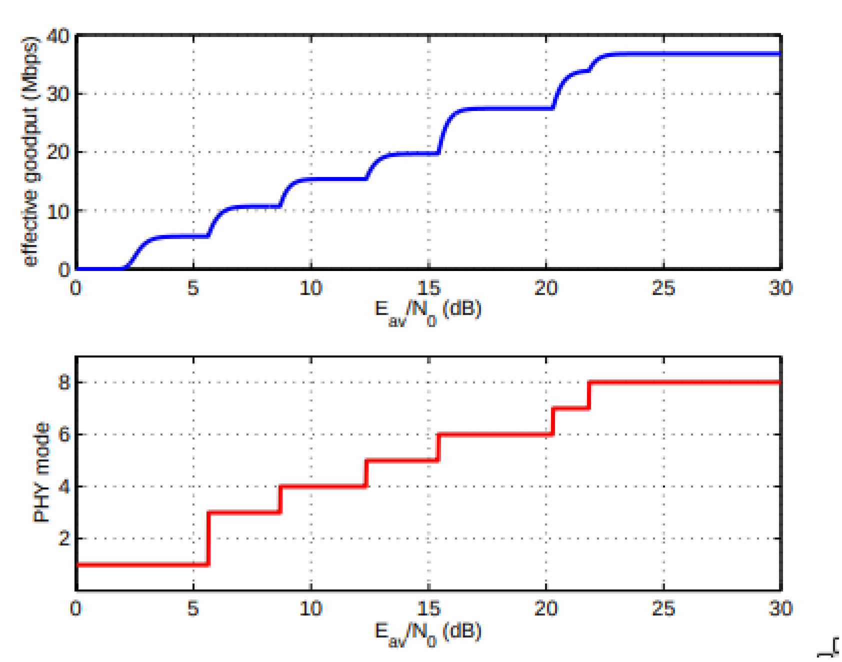

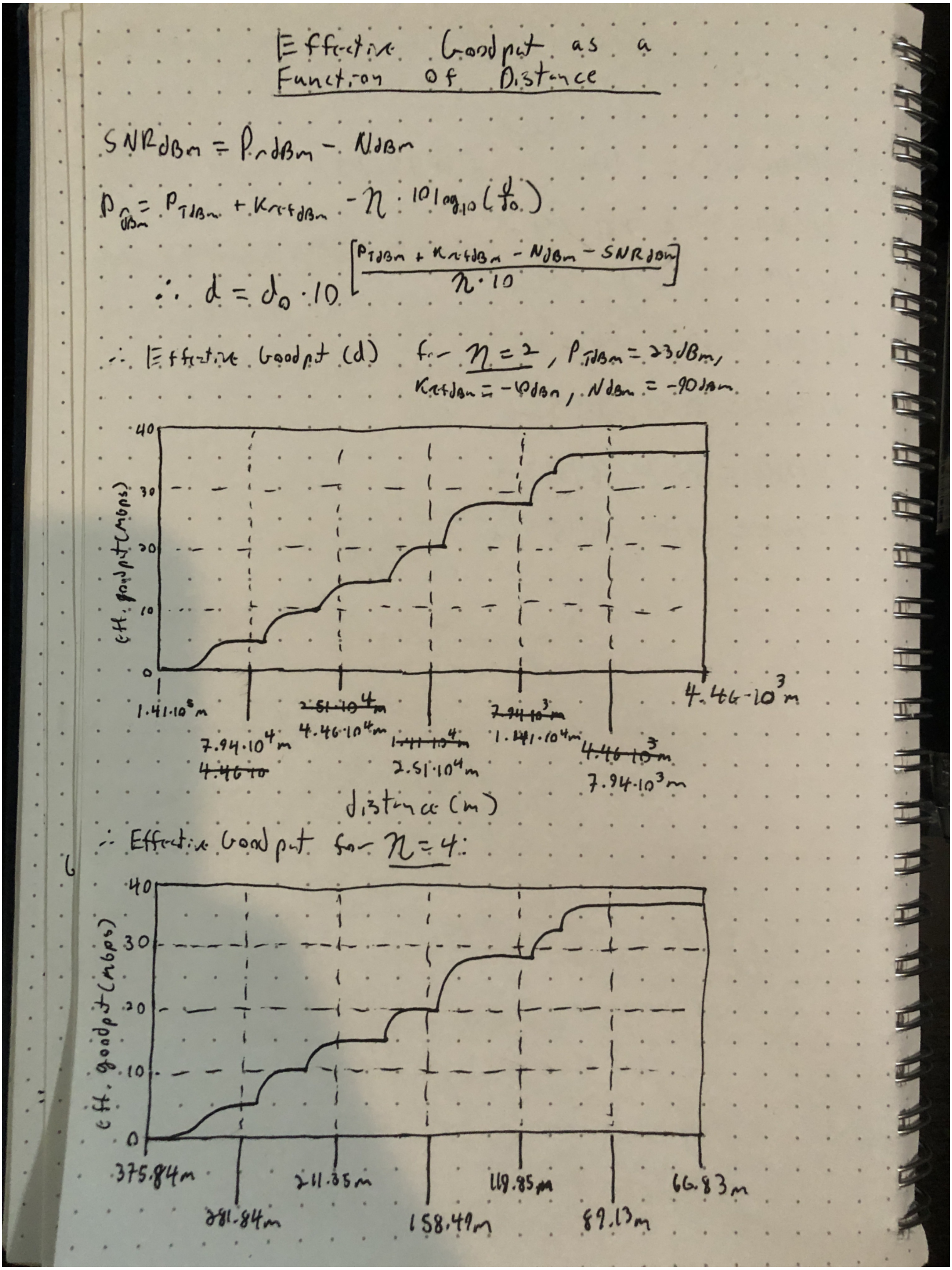

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mobile speed = 0:
p00 = 0.0780
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p10 = 0.1395
p11 = 0.6420

mobile speed = 5:
p00 = 0.0775
p01 = 0.1490
p10 = 0.1490
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mobile speed = 10:
p00 = 0.0715
p01 = 0.1430
p10 = 0.1425
p11 = 0.6425

mobile speed = 15:
p00 = 0.0655
p01 = 0.1570
p10 = 0.1575
p11 = 0.6195

mobile speed = 20:
p00 = 0.0750
p01 = 0.1420
p10 = 0.1420
p11 = 0.6405

mobile speed = 25:
p00 = 0.0810
p01 = 0.1485
p10 = 0.1485
p11 = 0.6215
d(SNR = 5) = 7.94E4m

ee597-assignment2

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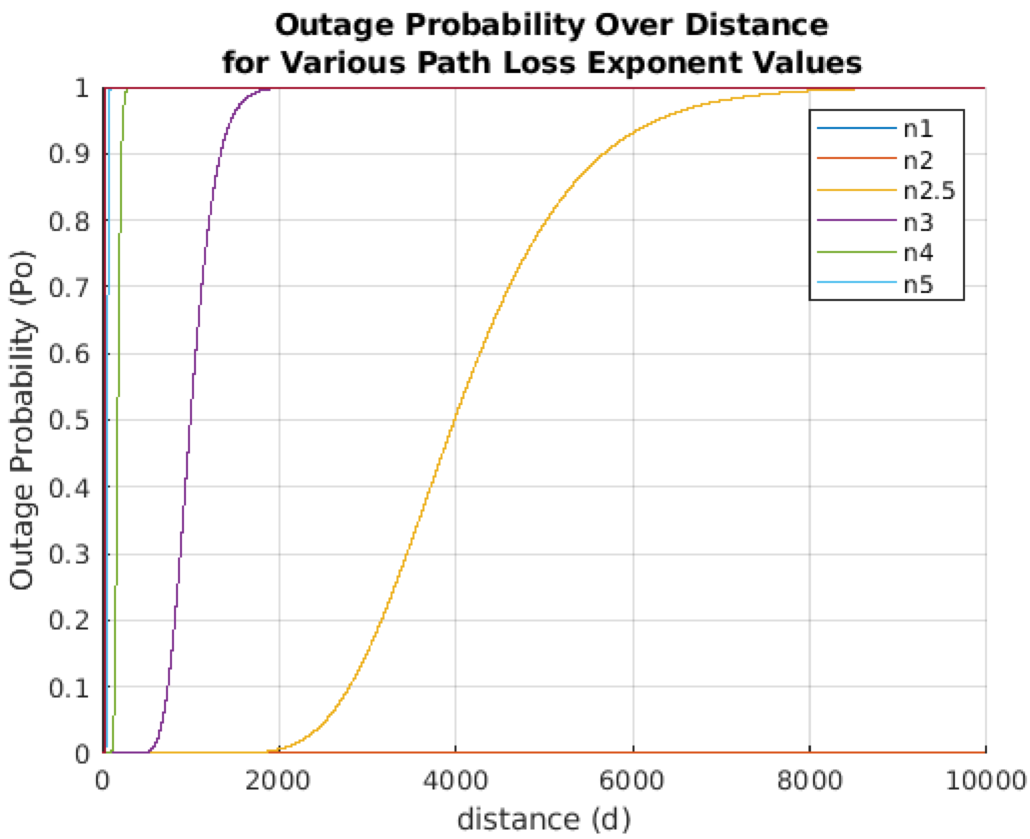

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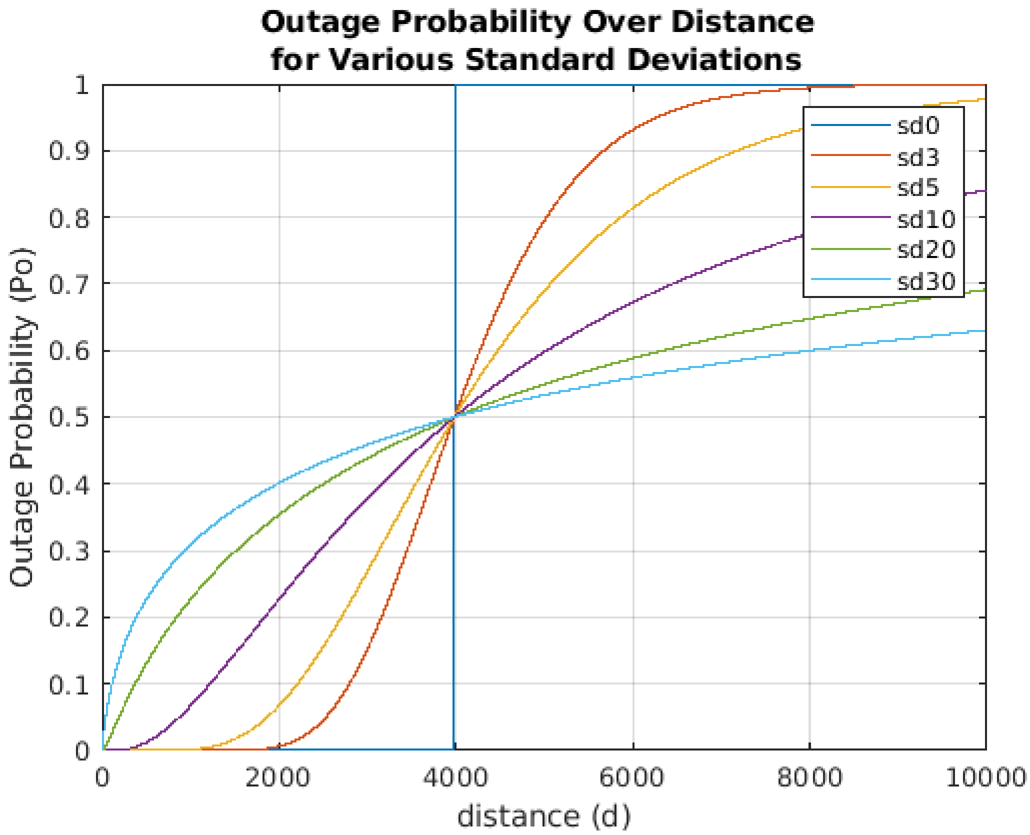

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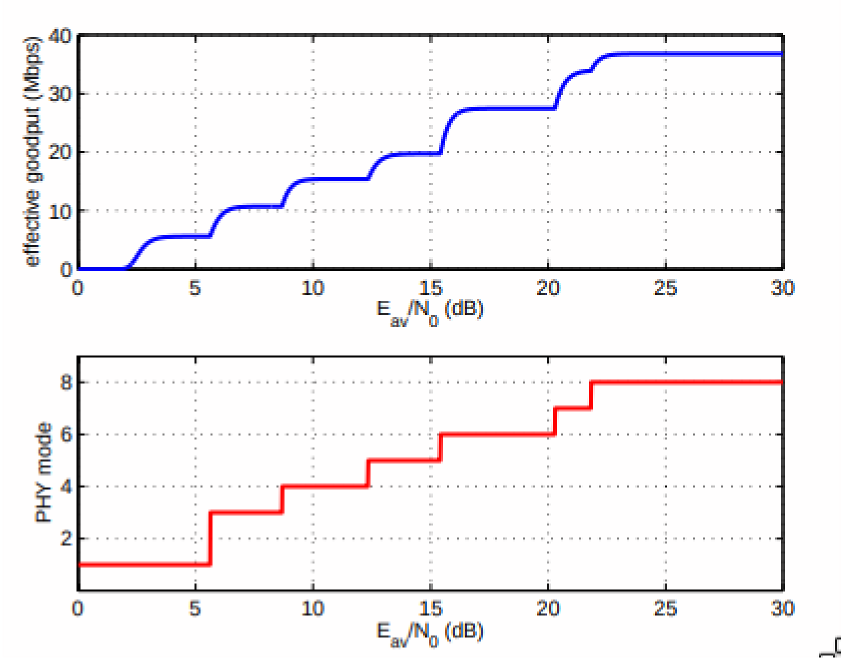

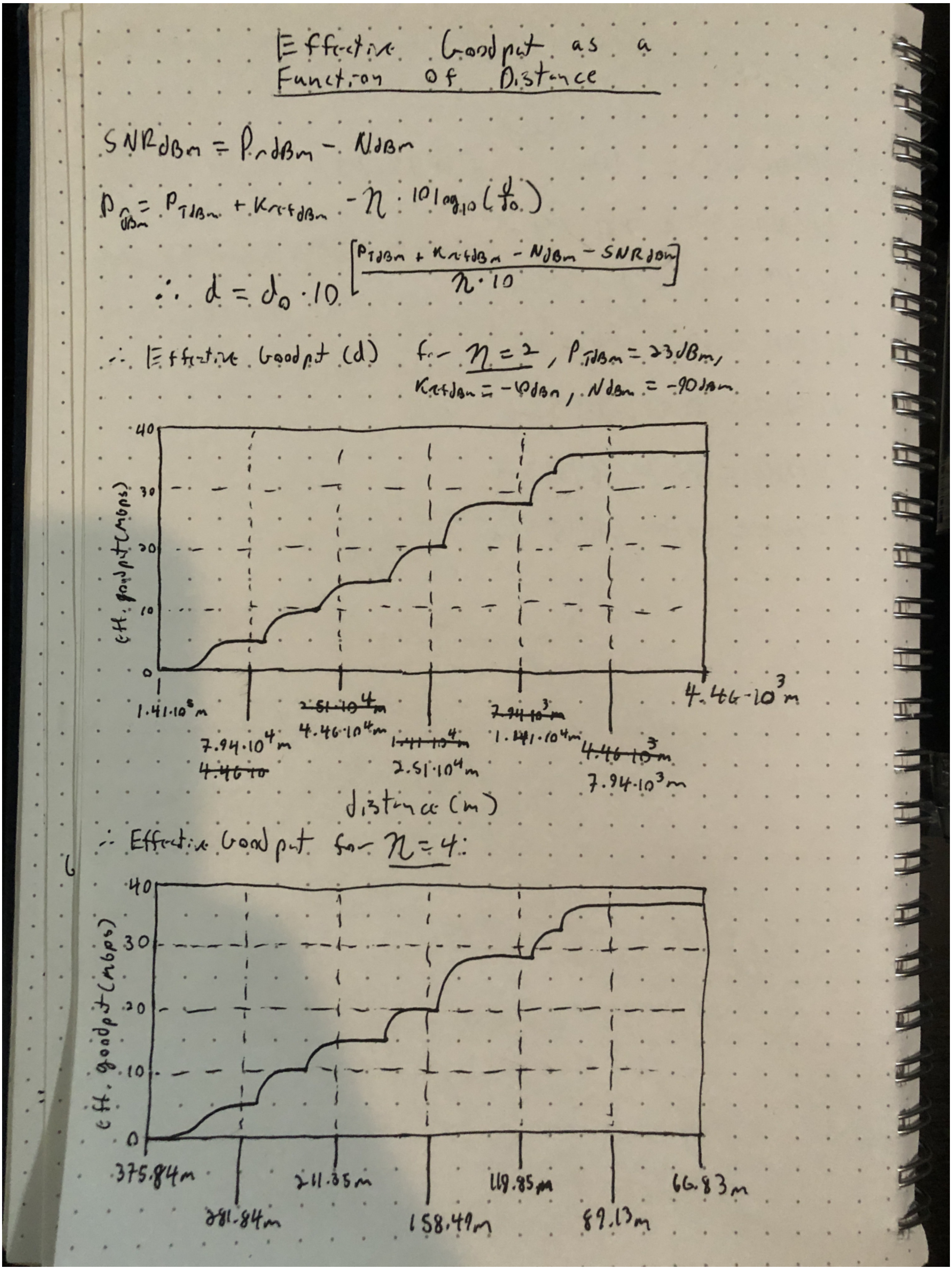

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d(SNR = 0) = 375.84m
d(SNR = 5) = 281.84m
d(SNR = 10) = 211.35m
d(SNR = 15) = 158.49m
d(SNR = 20) = 118.85m
d(SNR = 25) = 89.13m
d(SNR = 30) = 66.83m

Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

p00 - *the probability that we remain in the "outage" state*
p01 - *the probability that we move from the "outage" state to the "receive" state*
p10 - *the probability that we move from the "receive" state to the "outage" state*
p11 - *the probability that we remain in the "receive" state*

mobile speed = 0:
p00 = 0.0780
p01 = 0.1400
p10 = 0.1395
p11 = 0.6420

mobile speed = 5:
p00 = 0.0775
p01 = 0.1490
p10 = 0.1490
p11 = 0.6240

mobile speed = 10:
p00 = 0.0715
p01 = 0.1430
p10 = 0.1425
p11 = 0.6425

mobile speed = 15:
p00 = 0.0655
p01 = 0.1570
p10 = 0.1575
p11 = 0.6195

mobile speed = 20:
p00 = 0.0750
p01 = 0.1420
p10 = 0.1420
p11 = 0.6405

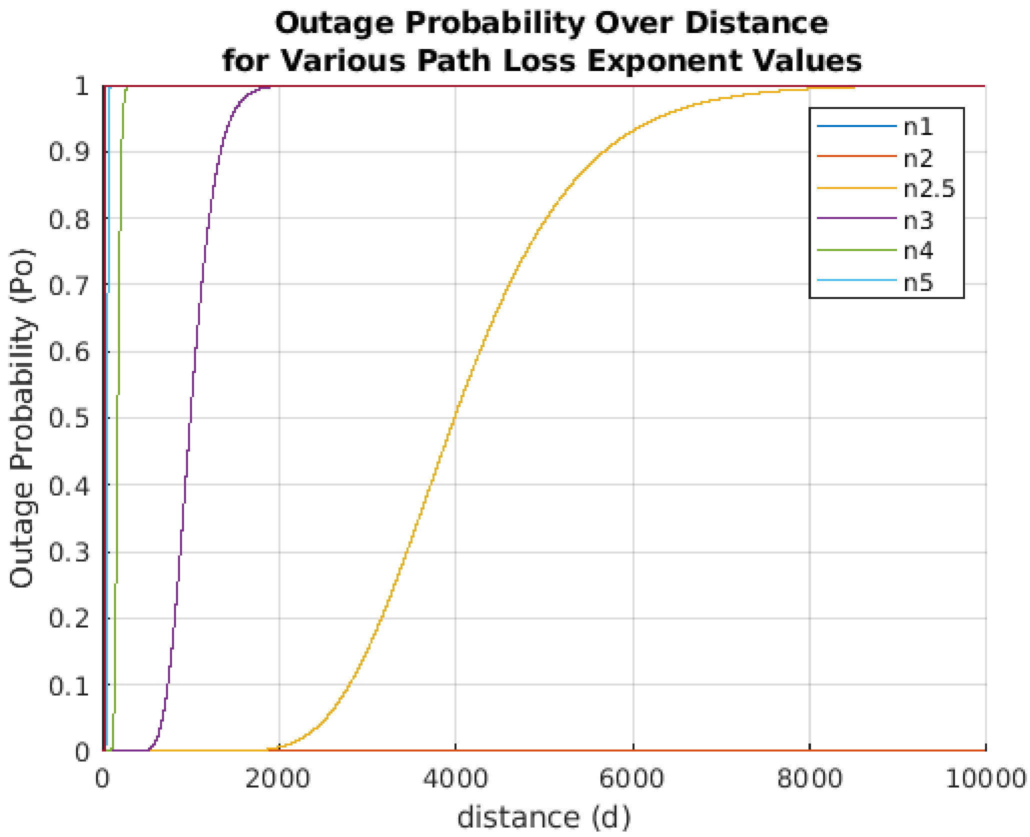
mobile speed = 25:
p00 = 0.0810
p01 = 0.1485
p10 = 0.1485
p11 = 0.6215
d(SNR = 10) = 4.46E4m

ee597-assignment2

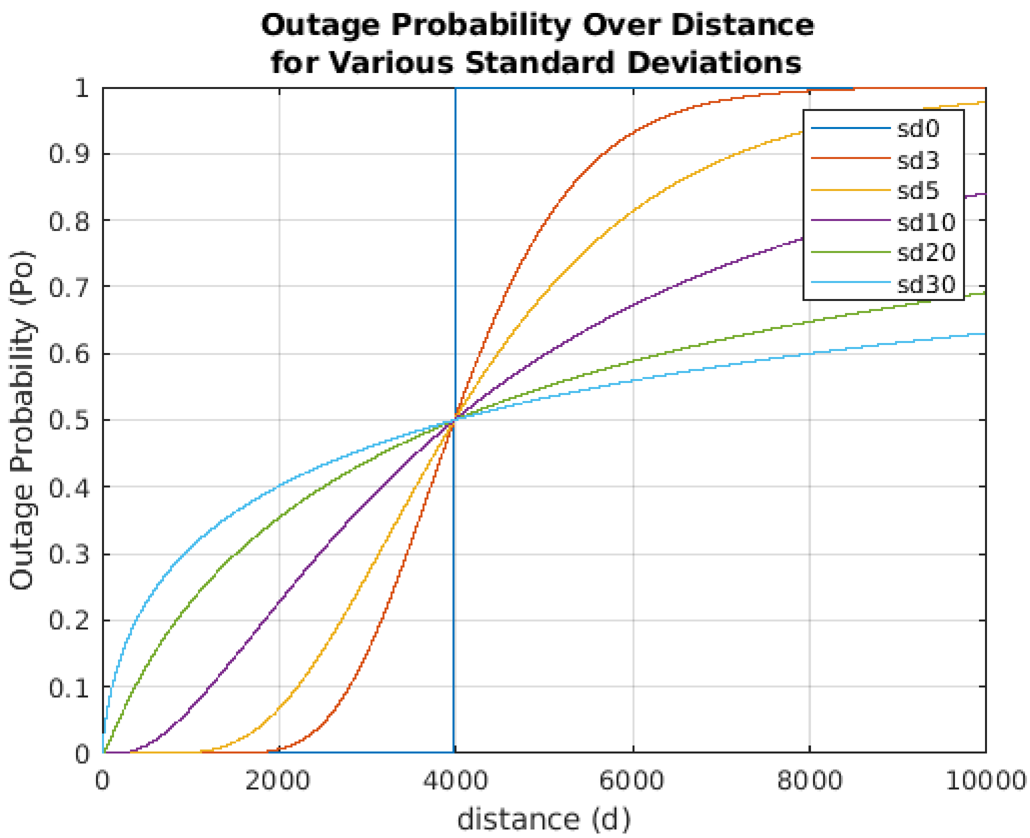
Determining outage probability as a function of distance for log-normal shadowing, rate adaption for varying ranges of SNR, and modeling Rayleigh Fading as a two-state markov chain.

by
Bill Wang student id: and Spencer McDonough student id:

Outage Probability as a function of distance for Log-Normal Shadowing



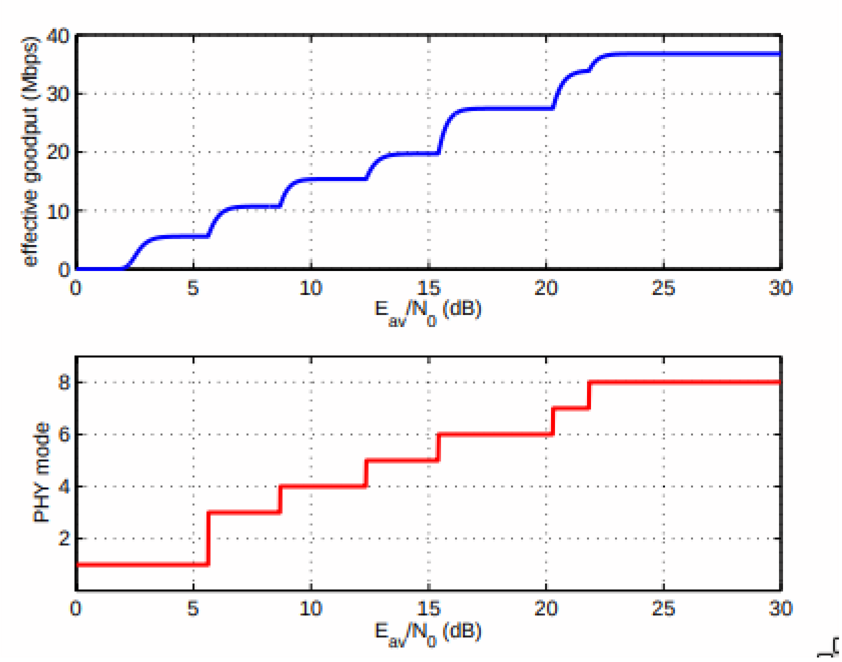
We can see that the probability of outage sigmoid function gets skewed left as we increase the value of the path loss exponent (PLE). This means that the probability of outage increases exponentially by a greater factor when the PLE is increased. This makes sense, as the PLE represents the attenuation due to the nature of the environment (heta > 2 : loss, heta = 2 : vacuum, or no loss, heta < 2 : gain).

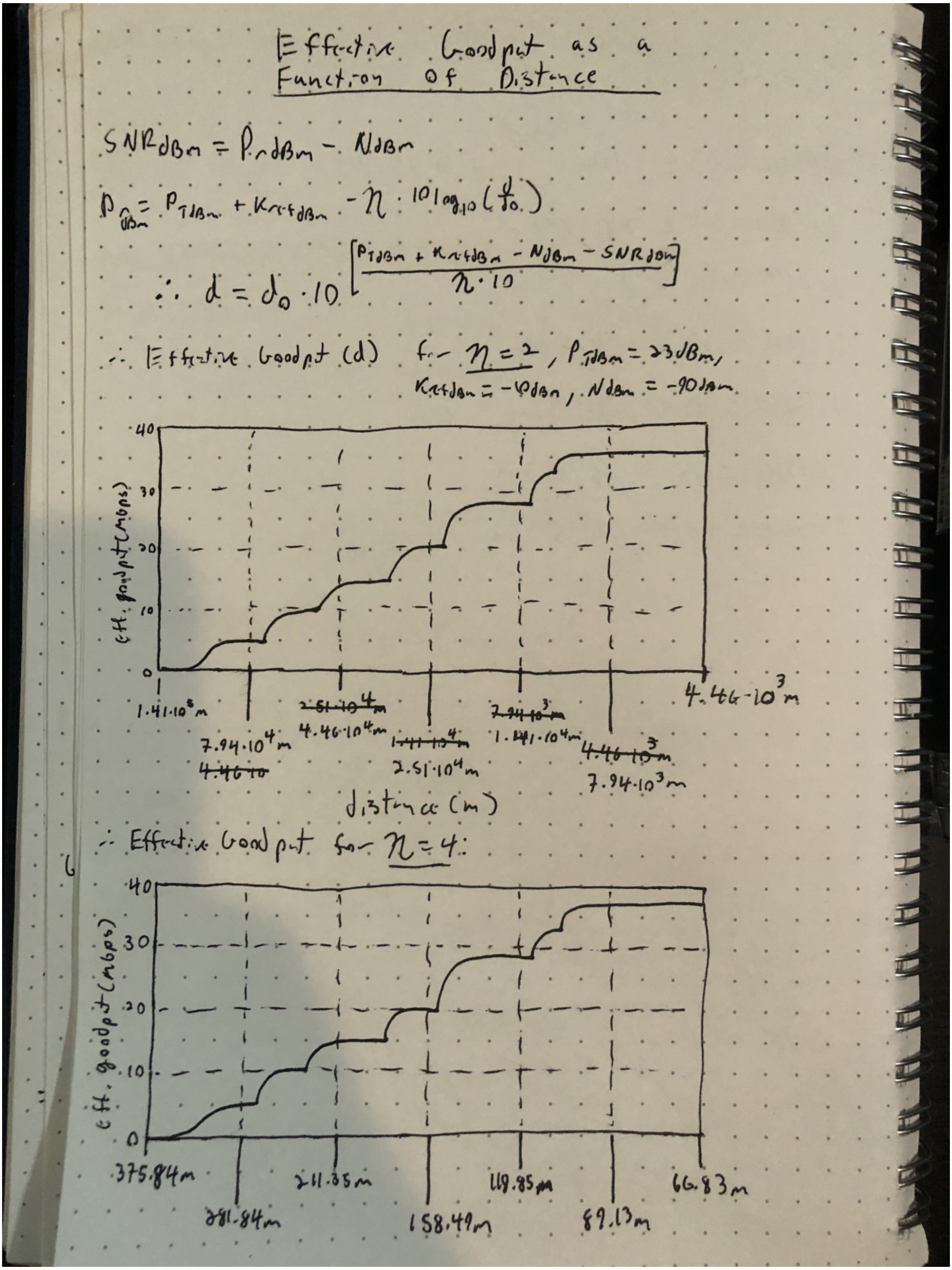


We can see that the probability of outage sigmoid function gets shallower as the standard deviation of the path loss exponenent (PLE) increases. This makes sense, as the probability of outage is inversely

proportional to the log of the PLE's standard deviation.

Rate Adaptation





In this exercise, we converted SNR to distance with a known path loss model. P_TdBm = 23dBm, P_{ref} = -10dBm, NdBm = -90dBm. We took figure 3 and converted the model from Goodput vs SNR to Goodput vs Distance (m) with heta values 2 and 4. Here is a breakdown of the SNR --> d(m) conversions for clarity: d = d0 * $10^{(PTdbm + Pref - NdBm - SNRdBm)/(heta * 10)}$

heta = 2:
d(SNR = 0) = 1.41E5m
d(SNR = 5) = 7.94E4m
d(SNR = 10) = 4.46E4m
d(SNR = 15) = 2.51E4m
d(SNR = 20) = 1.41E4m
d(SNR = 25) = 7.94E3m
d(SNR = 30) = 4.46E3m

heta = 4:
d(SNR = 0) = 375.84m
d(SNR = 5) = 281.84m
d(SNR = 10) = 211.35m
d(SNR = 15) = 158.49m
d(SNR = 20) = 118.85m
d(SNR = 25) = 89.13m
d(SNR = 30) = 66.83m

Rayleigh Fading

In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

p00 - *the probability that we remain in the "outage" state*
p01 - *the probability that we move from the "outage" state to the "receive" state*
p10 - *the probability that we move from the "receive" state to the "outage" state*
p11 - *the probability that we remain in the "receive" state*

mobile speed = 0:
p00 = 0.0780
p01 = 0.1400
p10 = 0.1395
p11 = 0.6420

mobile speed = 5:
p00 = 0.0775
p01 = 0.1490
p10 = 0.1490
p11 = 0.6240

mobile speed = 10:
p00 = 0.0715
p01 = 0.1430
p10 = 0.1425
p11 = 0.6425

mobile speed = 15:
p00 = 0.0655
p01 = 0.1570
p10 = 0.1575
p11 = 0.6195

mobile speed = 20:
p00 = 0.0750
p01 = 0.1420
p10 = 0.1420
p11 = 0.6405

mobile speed = 25:
p00 = 0.0810
p01 = 0.1485
p10 = 0.1485
p11 = 0.6215
d(SNR = 15) = 2.51E4m
d(SNR = 20) = 1.41E4m
d(SNR = 25) = 7.94E3m
d(SNR = 30) = 4.46E3m

heta = 4:
d(SNR = 0) = 375.84m
d(SNR = 5) = 281.84m
d(SNR = 10) = 211.35m
d(SNR = 15) = 158.49m
d(SNR = 20) = 118.85m
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In this exercise, we generated Markov Chain models to represent the likelihood that a receiver is in the state of "receive" or "outage." The Markov Chain models and their probabilities are associated with received power (in dBm) being above or below a threshold, dictating whether the received signal is strong enough to demodulate or not. We generated 6 models corresponding to mobile speeds [0, 5, 10, 15, 20, 25].

p00 - *the probability that we remain in the "outage" state*
p01 - *the probability that we move from the "outage" state to the "receive" state*
p10 - *the probability that we move from the "receive" state to the "outage" state*
p11 - *the probability that we remain in the "receive" state*

mobile speed = 0:
p00 = 0.0780
p01 = 0.1400
p10 = 0.1395
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p00 = 0.0775

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mobile speed = 10:

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mobile speed = 15:

p00 = 0.0655

p01 = 0.1570

p10 = 0.1575

p11 = 0.6195

mobile speed = 20:

p00 = 0.0750

p01 = 0.1420

p10 = 0.1420

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mobile speed = 25:

p00 = 0.0810

p01 = 0.1485

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p11 = 0.6215