Department of Electrical Engineering
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EE 5141 Introduction to Wireless and Cellular Communications
February – May 2021

Computer Assignment Submission Instructions

- Submit the assignment individually or as team of two students
- Please submit the following
  - Required plots
  - Include brief explanation of observations, as appropriate
  - Listing of code written by you

- The submitted file should be in .pdf format

- Mention name and roll number of both team members

- Use following naming convention for file you
  - roll_number_assign#.pdf
  - example: EE19Mxxx_assign5.pdf
  - Use roll number of one of the team members

- Assignment submission via Moodle
  - Instructions given by TAs
  - Do not send via email

- Honor Code:
  - Add this line to your assignment and an electronic signature
  - I certify that this assignment submission is my own work and not from obtained from any other source

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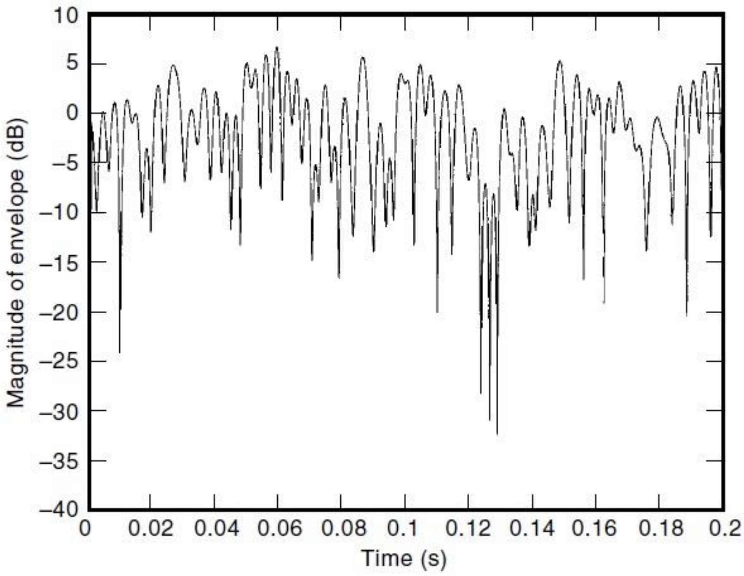
Computer Assignment # 5 (Due date: March 26, 2021)

Performance in Rayleigh Fading

1. The goal of this task is to use Jakes' method which is used to generate Rayleigh fading. The fading waveform must be sampled at the specified sampling rate (assume 1000 Hz, i.e., sampling period of msec), and the average received envelope should be 0 dB (normalization). Use $N_0 = 20$ oscillators.
   (a) Generate fading f_D=100 Hz for 1 second. Plot on dB scale. Indicate the maximum range of variation of the envelope in the segment you have generated. The variation will be similar to the graph given below.



2. The purpose of this task is to obtain the BER curve for DQPSK in Rayleigh fading. Generate a random sequence of about 512 symbols and apply pulse shaping with a square-root raised cosine (SRRC) pulse (roll off 0.35). Use an over-sampling ratio of 8x symbol rate and a truncation length of 10 symbols for the SRRC pulse. The symbol rate is 25 Ksymbols/sec. The receive filter is a matched SRRC filter. Assume perfect synchronization and ideal sample timing selection.

   (a) Introduce Rayleigh fading using the code provided for Jakes' model. The received signal is given by $(t) = Z(t)\,u(t) + \eta(t)$, where $Z(t)$ represents the Rayleigh fading and $u(t)$ is the complex baseband signal with pulse shaping. A sample code for generating Rayleigh fading using Jakes' model is provided.

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(b) The following information must be provided to the programme:

i. Doppler (in Hz)
ii. Time resolution (Tsample)
iii. Starting time of the oscillators (use time increments for each call of function to ensure uncorrelated fading for each burst)
iv. Number of samples of fading channel (# symbols in burst x8)

(c) Apply Rayleigh fading (as generated by the subroutine in part a) to your transmitted signal. Use a differential detector at the receiver. Evaluate BER in the range 10^{-1} to 10^{-3}, (with Eb/No increments in steps of 2 dB). Note that in order to get sufficient averaging, you should average over at least 3000 bursts, each with 512 symbols each. Assume that the Doppler frequency is 10 Hz.

3. Repeat Step (b) for 100 Hz and 900 Hz in steps of 200 Hz

4. Plot the performance for different Doppler frequencies along with the theoretical curve for BER for DQPSK. Explain your observations.
Given that,

$$BER_{DQPSK,Fading} = 0.5 * \left(1 - \frac{\sqrt{2}\Gamma}{\sqrt{1 + 4\Gamma + 2\Gamma^2}}\right)$$

where $\Gamma = \frac{E_b}{N_0}$.

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Jakes' Model for generating Rayleigh Fading (Matlab Code)

```
function Z=Jakes(fd, Tsample, t0, Num)
% Z=Jakes() - returns fading waveform generated using Jakes' model
% fd= maximum Doppler frequency
% Tsample= Time resolution of signal in seconds
% t0 = starting time of oscillators
% Num=Number of samples of fading to be generated

N0=20; %Number of oscillators
N=4*N0+2; %N is even but not multiple of 4
scale1=1/sqrt(2*N0); %Scale factor for real part of fading channel
scale2=1/sqrt(2*(N0+1)); %Scale factor for imag part of fading channel

n=1:N0; %Oscillator index
t = (0: Tsample:(Num-1) *Tsample) + t0; %Time duration
fn = fd*cos(2*pi*n/N); %fn – frequencies of oscillators in Jakes' model
alp=0;
beta=n*pi/(N0+1);
phi=2*pi*rand(N0,1); %Random phases for each oscillator

ZC1=zeros(1, length(t));
ZS1=zeros(1, length(t));
for k=1:N0
   %Real part
   ZC1=ZC1+2*cos(beta(k))*cos(2*pi*fn(k)*t+phi(k));
   %Imag part
   ZS1=ZS1+2*sin(beta(k))*cos(2*pi*fn(k)*t+phi(k));
end
ZC=(ZC1+sqrt(2)*cos(alp)*cos(2*pi*fd*t))*scale2;
ZS=(ZS1+sqrt(2)*sin(alp)*cos(2*pi*fd*t))*scale1;
Z=complex(ZC,ZS);
```

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